Manual of Photo-Technique

THE MANUALS OF PHOTO-TECHNIQUE

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Enlarging

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First published in 1939, C. I. Jacobson's "Enlarging" was the premier volume of the Focal "Manuals of Photo Technique." It met a greater need all over the world than any of the others that followed it. It ran into eighteen editions. The last of these, published in 1960, might have been reprinted several times since then to satisfy the never-ebbing demand for it.

However both author and publishers felt that the time had come to replace the much revised original work by a fundamentally new nineteenth edition, of which this twenty second is a further revision. Not only has it been re-written and re-illustrated from cover to cover, but the entire contents have been re-organised in order to apply a new approach to a changed technology and a wider scope. This work was done by L. A. Mannheim in co-operation with Dr. Jacobson.

The new book is now as useful to the professional who thinks and works in up-to-date terms as to the methodical amateur who aims at professional standards.

Its coverage ranges over both black-and-white and colour enlarging; from new theoretical conceptions of image evaluation to contemporary enlarger design; it deals with rapid processing methods and electronic masking alike.

Unchanged, however, is the long established spirit of the work in setting out even intricate technicalities in plain English without losing sight of the basic truth that whilst enlarging may still be the most complicated of all the processes that make up photography, it also remains a decisively creative phase of it.

The introductory paragraph of my Preface to the first Edition thirty-five years ago seems more valid than ever.

"Negative technique has become more and more automatic during recent years. The photographer has therefore turned logically to the production of his positives as an outlet for his technical imagination and ingenuity. Accordingly the development of the positive process has taken an opposite direction to the negative process and is evolving towards greater individualism and sublety."

The new version of this well-tested work continues the job of helping in that direction.

A. Kraszna-Krausz.

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The Function of Enlarging

In the classical photographic process the negative is an intermediate step. Its most obvious characteristic is that it shows all tone values of the original subject in reversed relationship: what was dark to darker in the subject is light to lighter in the negative, and vice versa. (We are for the moment confining ourselves to black-and-white negatives; colour negatives – page 70 – also show a more complex reversal of colour values.)

The final result of the photographer's work is a positive. Usually this is a print on paper, and one of the problems involved in producing it is that of once more reversing the tone scale of the negative image to yield a new picture whose tone values correspond to those of the original subject.

This problem is not only a technical one. The production of a "picture" in the full sense of the word also involves aesthetic considerations.

The tonally reversed negative image is a by-product of th way in which light acts on what is still the most widely usec photo-sensitive material: the silver halide emulsion. There are also processes which use an intermediate positive rather than negative stage. Their application is usually more specialised, and they will be dealt with in this book as they arise. Apart from the tonal reversal, the functional considerations are however similar for most such intermediate images.

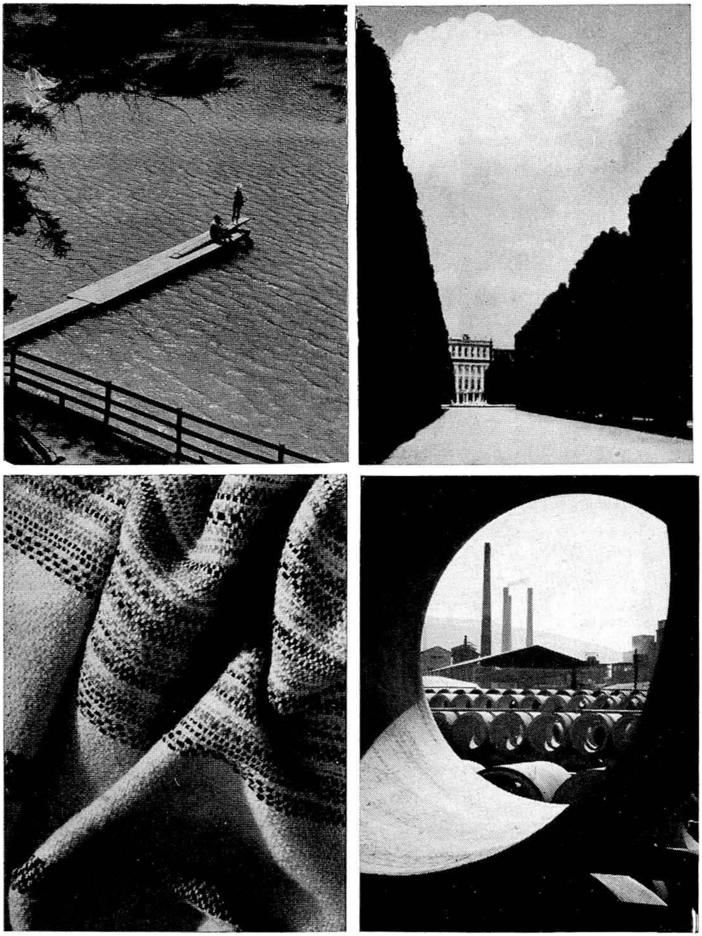
THE SCOPE OF ENLARGEMENT

Having a negative as an intermediate stage of the photographic picture has two main advantages:

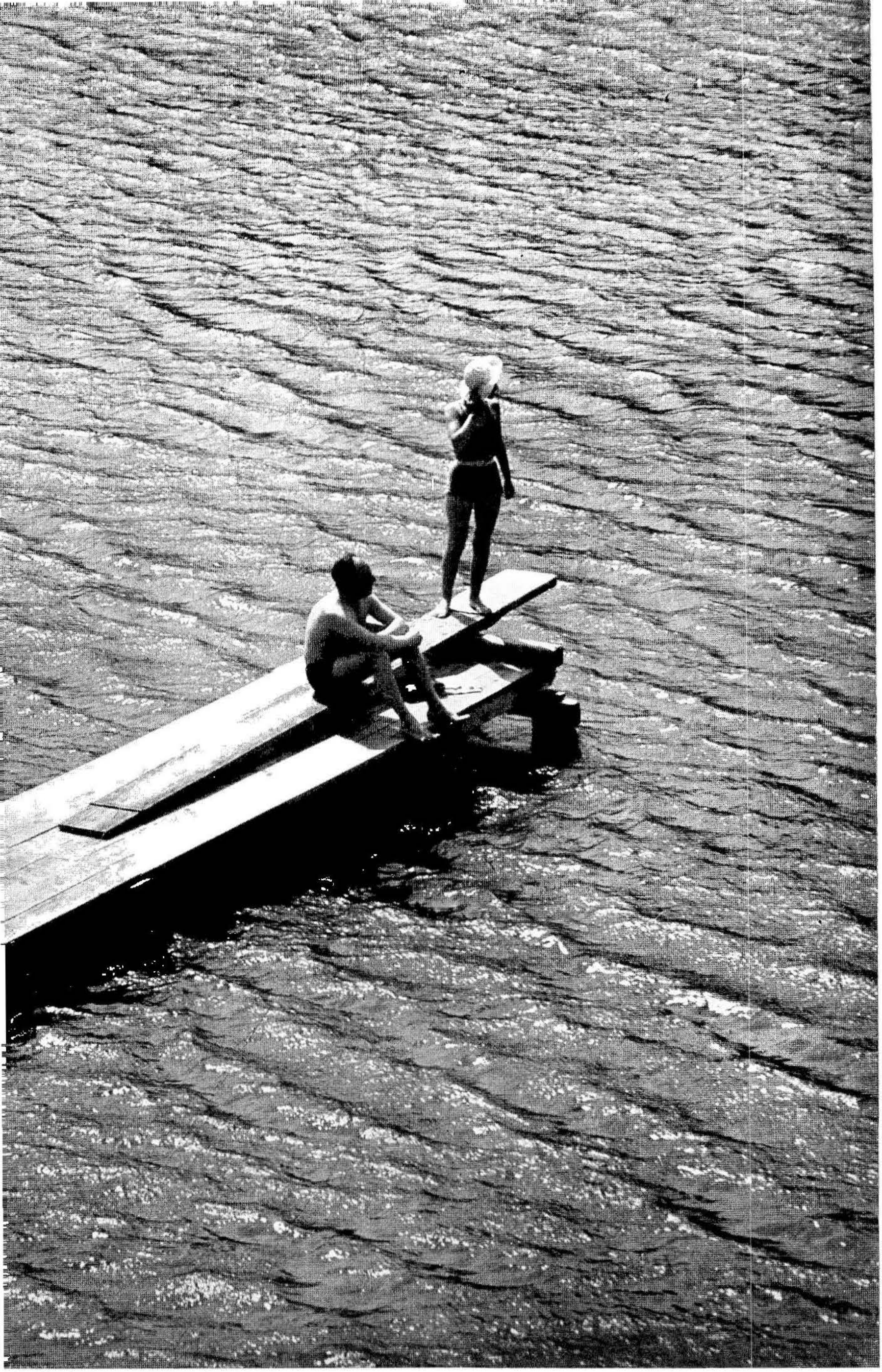
(1) The size of the camera does not have to be very closely related to the size of the final picture.

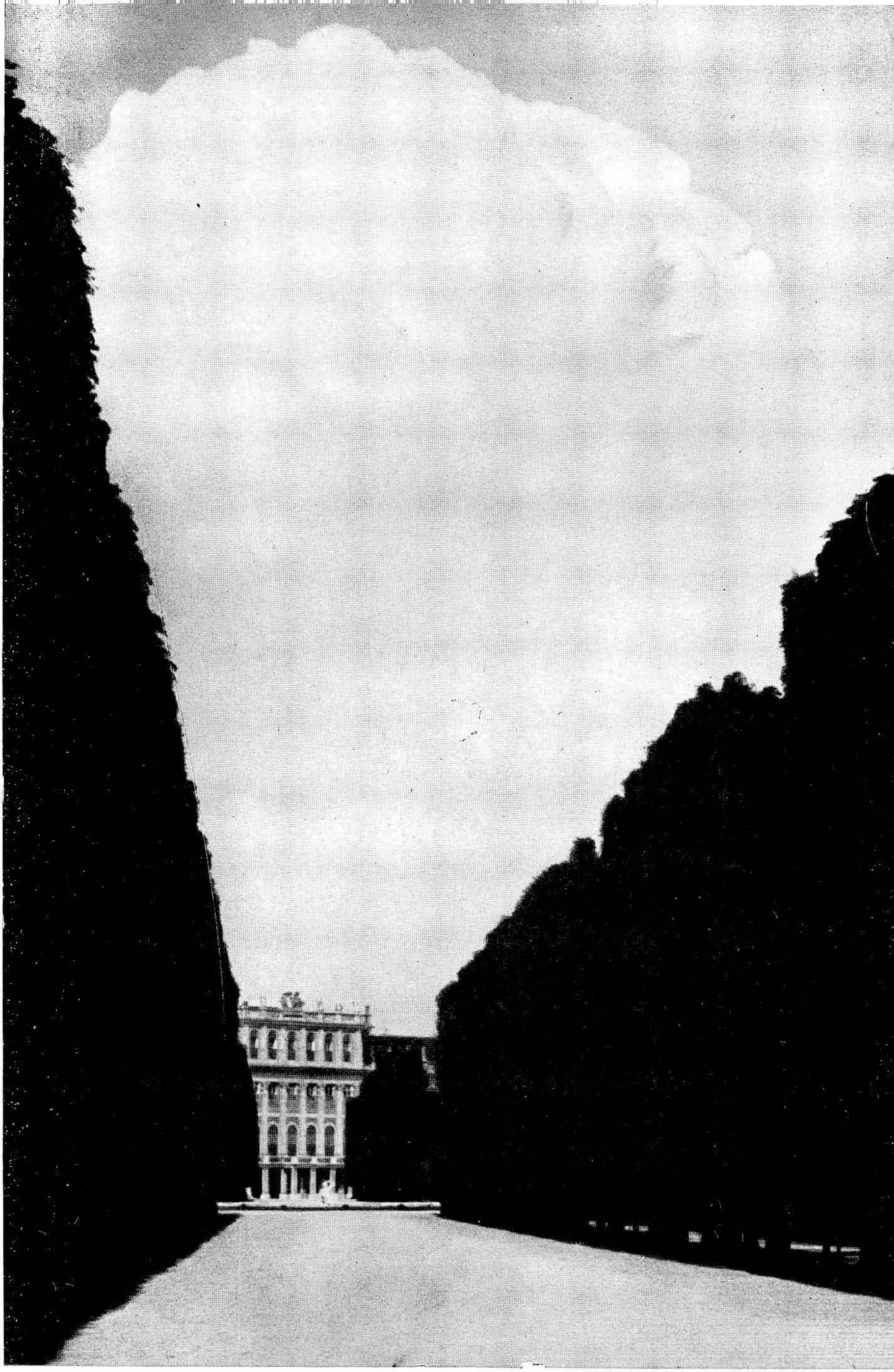
(2) Considerable technical as well as artistic control is possible during the process of making the positive print.

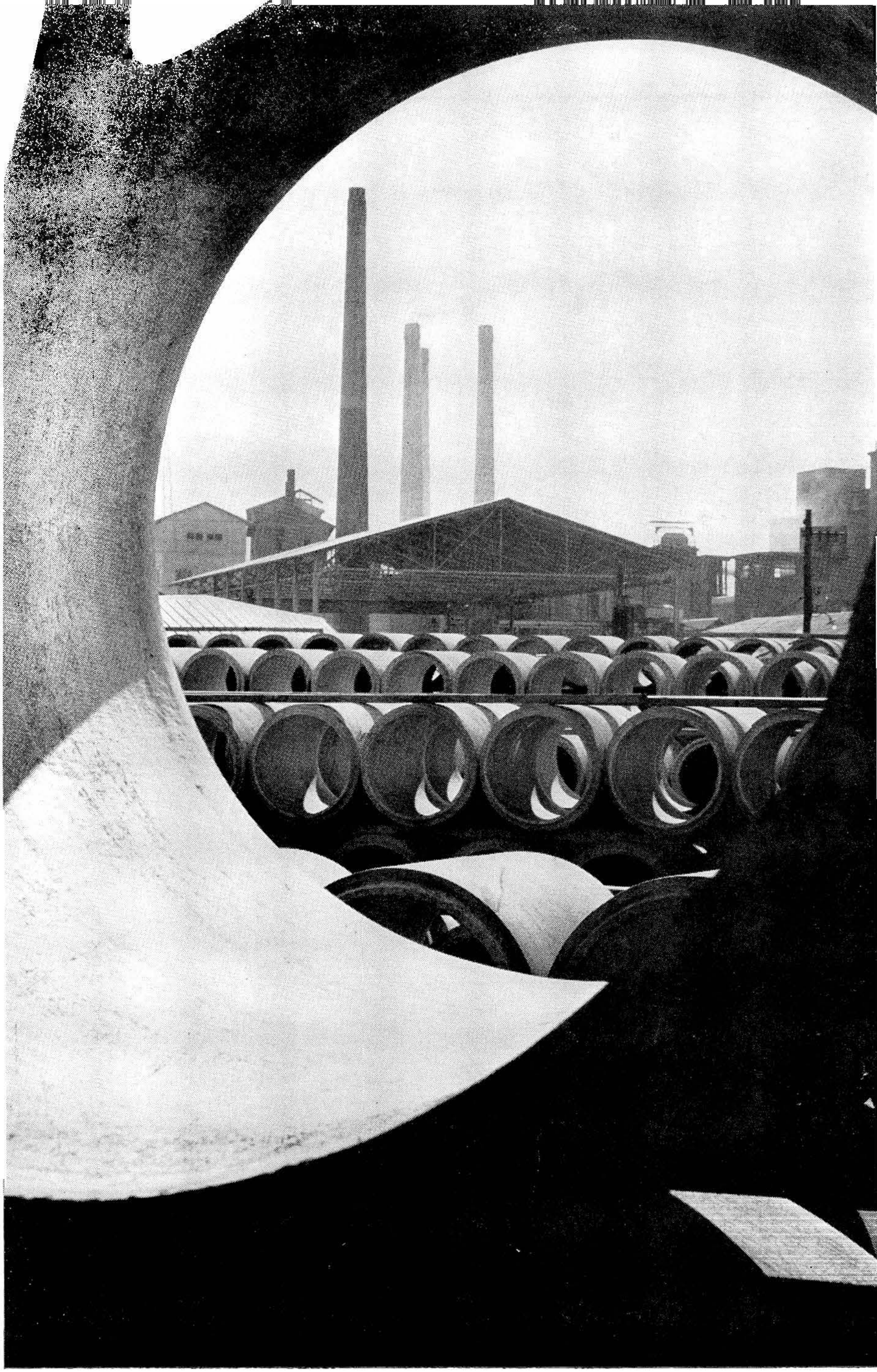
Enlarging, also known as projection printing, uses an optical projection system to produce an image of the negative

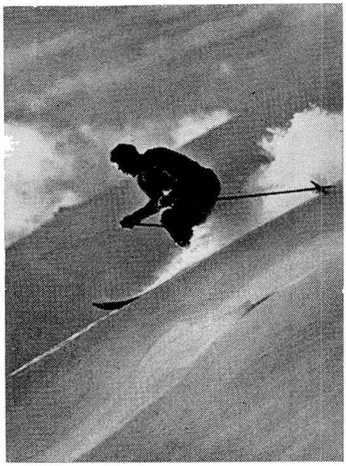


THE VALUE OF THE ENLARGING PROCESS. A comparison on these four contact prints with the corresponding enlargements of pages 18 to 21 shows how the appearance of the image is enhanced by the larger scale of presentation.









Page 18: A section only of the original negative turns out to have a better pictorial effect than the whole scene.

Page 19: The perspective effect of the enlargement is improved.

Page 20: The surface structure of the original subject becomes clearer in the enlargement, and details become visible which are barely seen in the contact print.

Page 21: The enlargement conveys a better feeling of space; the objects in the scene gain depth and appear more "rounded". Photo: *Rudolf Bieri.*

RISKS IN ENLARGING PROCESS. In an enlargement shortcomings of the negative become apparent which are frequently unnoticed in a smaller print (*above*).

Page 23: Until a negative has been enlarged, it is difficult to realize that it is not perfectly sharp. This may in some cases be a source of trouble, though in others it may be useful. (Slight lack of sharp definition tends to accentuate the rapid movement of the subject.)

Page 24: The enlarged image may show grain. This is rarely desirable, but not always avoidable.

in another plane, the sensitive paper being placed in this second plane to receive it. The optical arrangement is similar to that of a slide or cinema projector, and the positive image obviously does not have to be the same size as the negative – it can be any convenient size. Since projection printing is in most cases used for increasing the size of the image rather than for reducing it, we commonly refer to this printing process as enlarging. (In making for instance film prints from cine negatives, projection printing usually produces same-size or reduced positives.)

Hence point (1) mentioned above is particularly significant because nearly all present-day amateur cameras and a large proportion of professional instruments produce appreciably smaller negatives than the format of the final picture required. Reliance on this principle of small negatives for big prints has made the design and use of current compact cameras of miniature format possible. However, enlargement is also the standard way of printing larger-size professional negatives (e.g. 6 × 9 cm to 4 × 5 inches and larger) because this way we get prints of different sizes according to the purpose for which they are required.

As far as point (2) is concerned, having the positive image in a different position from the negative enables us to modify it in many ways. We can recompose the picture, leave out parts of it, modify tonal values, alter the image sharpness, and even change the actual objects shown in the negative or combine two or more of them.

CONTACT PRINTING

At a time when camera formats for general and amateur photography were appreciably larger, contact printing was a popular way of making the final positive. This involves placing the sensitive paper in intimate contact with the negative, so that the positive image is identical in size with the negative one. This procedure is simpler, especially in the equipment involved, than enlarging – but of course far less flexible. Nowadays, when the most frequent negative formats even for photographic beginners range between 13 × 17 and 24 × 36 mm, negatives are invariably enlarged even if only an album print is required.

For the advanced amateur and professional photographer contact prints serve at most as an identification aid of

negatives – for instance for filing or selection of negatives to be enlarged. Details such as facial expression are not easy to assess in a tonally reversed negative image, and even a small positive greatly helps.

Contact positives are nowadays employed only in special fields such as office document copying, and in reversal and transfer processes where the positive image is formed either in the same or in a contacting emulsion layer in the course of processing. This is the case with colour transparencies on the one hand and the transfer prints produced in instant-picture cameras on the other. The former need no enlargement since the transparencies are viewed by projection on a screen; transfer prints are subject to all the size limitations of a medium-format contact print – which is why instant-picture cameras tend to be comparatively large.

Methods and special applications of contact printing are discussed in more detail on pages 477 and 501.

THE DEGREE OF ENLARGEMENT

There is little question of the need for enlarging. The size to which negatives are enlarged needs more elaborate consideration. We can look at this from three points of view:

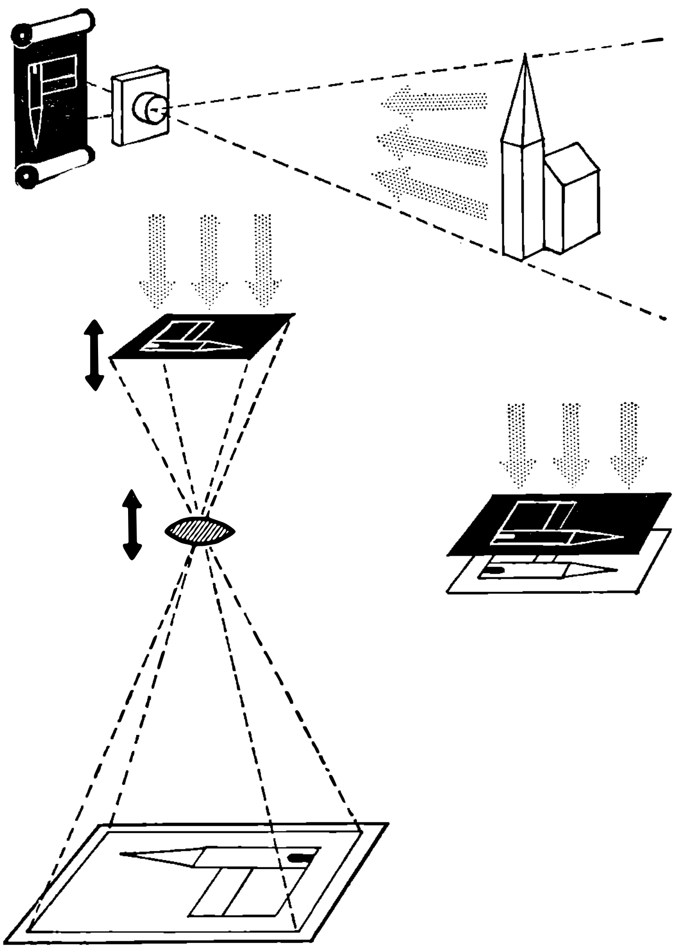
(1) The function of the print;
(2) Image appearance; and
(3) Image quality.

The first point is primarily a matter of the purpose for which the prints are required. We can very roughly group degrees of enlargement – in terms of the final print size – as small, medium to large, and very large. The degree of enlargement in diameters (the linear factor) will in every case depend of course on the size of the original negative.

Small Enlargements, 9 × 12 cm and to 4 × 5 inches, are mainly in the domain of the amateur who wants prints for his album. They represent the bulk of the output of photo-finishing laboratories and are generally made on automatic enlarging equipment to fixed ratios (En-prints and various other trade descriptions).

Medium-format Enlargements to 18 × 24 cm and 8 × 10 inches are the most common print sizes produced by professional photographers for publication in newspapers,

ENLARGING PRINCIPLES



The enlarging process is the counterpart of what takes place in the camera. There (*top*) light from the subject is projected by the lens on to the comparatively small film. In enlarging (*lower left*) the illuminated negative is projected on to the sensitive paper to give a large positive picture. By moving the negative and the lens we can adjust the degree of enlargement.

In contact printing (*centre right*) the negative and positive paper are in direct contact (here shown separated for clarity) so that light coming through the negative produces a positive picture of the same size.

catalogues etc. This also covers display prints produced by commercial portrait studios.

Big Enlargements of 25 × 30 and 40 × 50 cm or 10 × 12 to 16 × 20 inches figure mainly as exhibition prints by advanced amateur and professional workers as well as for decorative display in the home, shop windows and other advertising purposes.

Extra Big Prints from 0.6 × 1 m or 2 × 3 feet to wall-size are sometimes used as photo murals and other giant displays. Such enlargements usually require special equipment both for exposure and processing (page 467).

Apart from the pure functionalism of enlarging we have discussed so far, various optical and psychological factors enter into the choice of the print size, especially when the picture is an end in itself and not another intermediate step to further reproduction. These questions will now be considered to appreciate just what the process can do.

THE PROBLEM OF CORRECT PERSPECTIVE

When producing a photographic picture – at any rate one which is the final step of the process – we attempt to reproduce objects not only in their correct tone values, but also in their correct shapes and relative sizes. Ideally the picture should show the scene as the eye would have seen it from the viewpoint of the camera. This is a matter not only of viewpoint but also of the relative angles which different objects in the scene subtend at the camera lens.

There is a simple but important rule governing this: the perspective effect of an image will only appear correct when the image itself is viewed from a distance equal to the focal length of the lens which produced it in the camera.

This condition can in fact rarely be fulfilled. The average human eye cannot see objects clearly at a closer range than some 25 cm or 10 inches, while lenses used in cameras have focal lengths ranging from a fraction of this distance to a considerable number of times its value. Although we thus have here two sets of facts which appear mutually exclusive, the enlarging process can make them compatible.

For example let us consider a 24 × 36 mm negative taken by a miniature camera with a 50 mm lens. A contact print (or the original negative itself) must be viewed from 50 mm or 2 inches distance to show the correct perspective

effect. Yet we cannot look at it that close except with a magnifying glass. At the ideal viewing distance of 25 cm two difficulties appear: details are too small to be seen clearly, and the perspective effect is wrong (page 31).

Consider the case where the viewing distance is greater than the focal length of the lens which took the picture. The angle which the different objects in the original scene subtended from the viewpoint of the lens is greater than the angle they do in the picture from the viewpoint of the eye. As a result the perspective appears exaggerated – a familiar effect when we look at pictures taken with a wide angle lens (page 31).

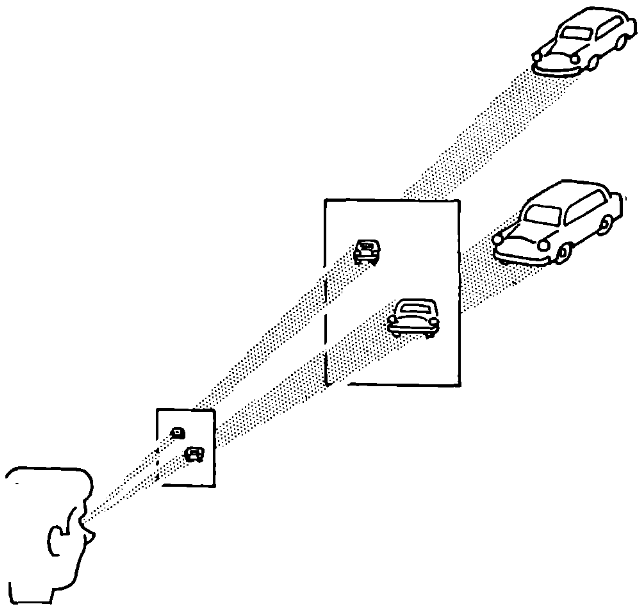
On the other hand we might have to look at a picture from a closer distance than the focal length of the lens used to take it. Now the angles of objects subtended from the viewpoint of the lens are narrower than when we actually look at them in the picture. This subdues the perspective and leads to the curiously foreshortened or squashed effect noticeable for instance in telephoto views. This is however less frequently met with in ordinary practice.

If the distance at which we view a print is the same as the focal length of the lens used in the camera, the viewing angles of all objects in the picture are the same as they were in the original scene. Hence the proportions appear natural and the eye receives a correct impression of perspective.

It follows from the above that to get a truly satisfactory perspective effect in a photograph the problem is usually one of increasing the focal length of a camera lens. This may be done either by actually choosing a lens of greater focal length for use on the camera, or by enlarging the negative taken with a shorter-focus lens. In the latter case we merely have to enlarge the image until it has the same effect as one taken with a lens of 250 mm or 10 inches focal length. With a miniature camera negative taken with a 50 mm (2 inch) lens this involves an enlargement of five diameters, which reconciles the conditions of viewing distance and focal length.

THE OPTIMUM DEGREE OF ENLARGEMENT

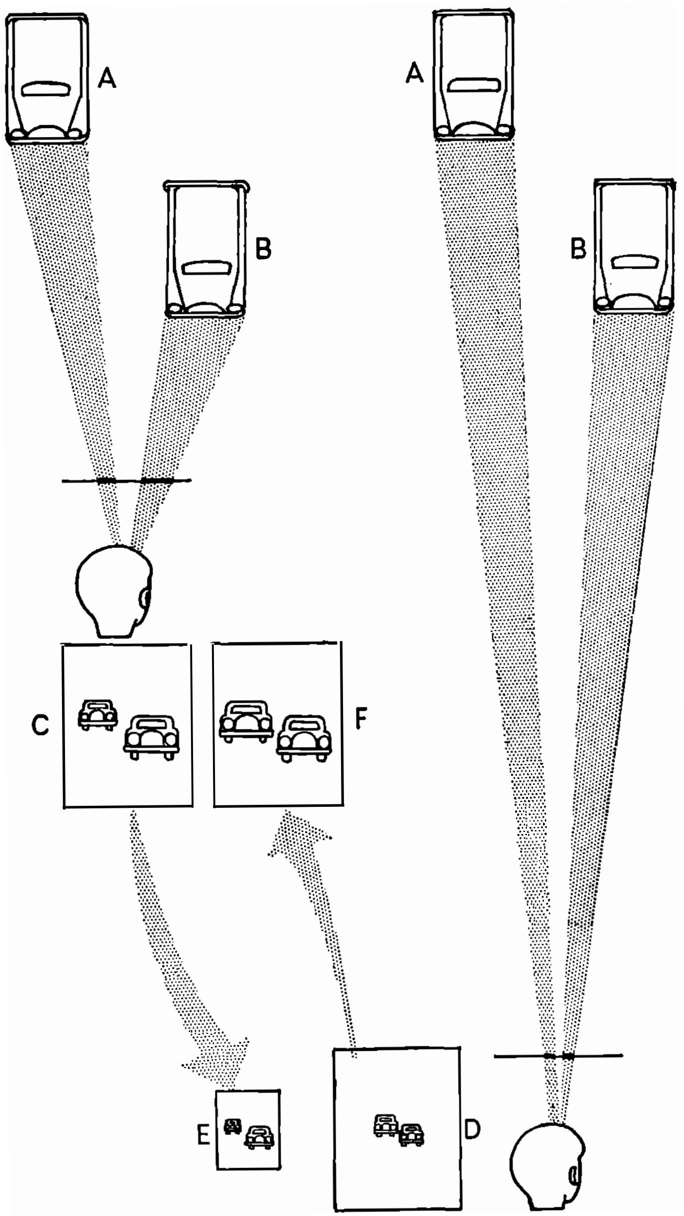
To obtain a natural perspective when viewing a print at a normal distance of 25 cm (10 inches) the negative therefore should be enlarged by a factor of 10 divided by the



Above: An object subtends a certain angle at the eye, depending on the size and distance of that object. As long as its image in a picture subtends the same angle, the viewing perspective is correct. That would apply equally to a small print viewed from close up, or to a larger one from farther away.

Opposite: When seen from a near viewpoint the two cars A and B, at different distances from the observer, appear different in size, so producing the typical perspective effect of image C. When photographed from farther away, not only are the cars smaller as in D, but also more similar in size since the difference in the distances of the cars is less compared with the camera distance.

If now the picture C is viewed from too far away, the visual scale of the cars may be as shown in E, but the perspective is wrong, since it should be more like D. Conversely, if the picture D is viewed from too close a distance, the visual image scale becomes more like F – i.e. similar to the scale of C at which the perspective (which is still that of D) is wrong. This is typical of pictures taken with tele lenses.


A
B
A
B
C
F
E
D

focal length of the camera lens in inches. Table I below compares such optimum magnifications for different negative formats and camera lenses. This table refers to the "normal" focal length for each negative size, in other words the focal length which corresponds approximately to the negative diagonal. For this reason the final print sizes quoted are fairly similar, or at least of the same order, mostly around 13 × 18 to 17 × 21 cm.

I – OPTIMUM ENLARGEMENT FOR NATURAL PERSPECTIVE

Negative Size (Nominal)	*Focal Length of Lens* mm	in.	*Diameters of* Enlargement*	*Final Print* size (approx.)* inches	cm
8 × 11 mm	15	⅗	16·5	5¼ × 7¼	13 × 18
10 × 14 mm	25	1	10	4 × 5¾	10 × 14
13 × 17 mm	25	1	10	5 × 6¾	13 × 17
18 × 24 mm	28–30	1⅛	8·5	6 × 8	15 × 20
24 × 24 mm 26 × 26 mm	38–40	1½	6·3	6 × 6 6½ × 6½	15 × 15 16 × 16
24 × 36 mm	45	1¾	5·6	5¼ × 8	13 × 20
24 × 36 mm	50	2	5	4¾ × 7	12 × 18
1¾ × 2¼ in. (4·5 × 6 cm)	75	3	3·3	5¾ × 7½	14 × 19
2¼ × 2¼ in. (6 × 6 cm)	80	3⅛	3·1	7 × 7	18 × 18
2¼ × 3¼ in. (6 × 9 cm)	100	4	2·5	5¾ × 8¼	14·5 × 21
3¼ × 4¼ in. (9 × 12 cm)	135	5⅜	1·9	6 × 8	17 × 22
4 × 5 in. (10 × 12·7 cm)	150	6	1·7	6½ × 8½	17 × 21

* For a viewing distance of 25 cm or 10 inches.

This assumes that the whole of the negative is being enlarged. Where the image is cropped by leaving out parts of it – one of the most obvious ways in which we can control the composition of the final picture – the optimum print size would be appropriately reduced.

On the other hand for display enlargements such as exhibition prints which are to be viewed at greater distances, the optimum degree of enlargement is also greater. Thus a 16 × 20 inch enlargement from a 35 mm negative taken with a 50 mm lens involves a magnification of about 14 diameters and the optimum viewing distance for correct

perspective becomes about 28 inches. This is also important because high-magnification prints seen from too close a distance tend to show both disturbing graininess and loss of image detail. These two points adversely affect the impression of a print as much as does wrong perspective. We shall come back to these factors on pages 49 and 56.

PRACTICAL MAGNIFICATION PROBLEMS

In practice we often cannot insist on this ideal relationship of magnification and viewing distance. In the first place, where pictures end up as reproductions in newspapers, periodicals or books, the photographer has little control over the final degree of enlargement. And in looking at published photographs we rarely have a definite clue to the correct distance at which such pictures should be viewed. So most of the time we look at them from some indeterminate convenient distance, 25 cm (10 inches) or more, and put up with any lack of natural depth. Such lack is further emphasised by the loss in tone quality which photographs almost invariably suffer on reproduction in print.

Secondly, professional photographers using miniature and medium format cameras often employ interchangeable lenses. Their purpose in this case is (a) to increase or decrease the angle of view of the camera, and (b) to decrease or increase respectively the image scale without any reference to ideal viewing distances or specific print formats.

II – ENLARGEMENTS FROM 24 × 36 mm. NEGATIVES

Focal Length of Lens (mm)	*Diameters of* Enlargement*	*Final Print* Size* inches	cm	*Required Viewing Distance for a 13 × 18 cm or 5 × 7 inch print* inches	cm
21	12	$11\frac{1}{2} \times 17\frac{1}{2}$	29 × 42	4	10
28	9	$8\frac{1}{2} \times 13$	21 × 30	$5\frac{1}{4}$	15
35	7·2	$6\frac{3}{4} \times 10\frac{1}{4}$	17 × 26	$6\frac{3}{4}$	17
50	5	$4\frac{3}{4} \times 7$	12 × 18	10	25
90	2·8	$2\frac{5}{8} \times 4$	6·7 × 10	$17\frac{1}{2}$	45
135	1·9	$1\frac{3}{4} \times 2\frac{3}{4}$	4·4 × 6·6	25	68
180	1·4	$1\frac{3}{8} \times 2$	3·3 × 5	35	90
300	0·85	$\frac{3}{4} \times 1\frac{1}{4}$	2 × 3	56	150
500	0·5	$\frac{1}{2} \times \frac{3}{4}$	1·2 × 1·8	100	250

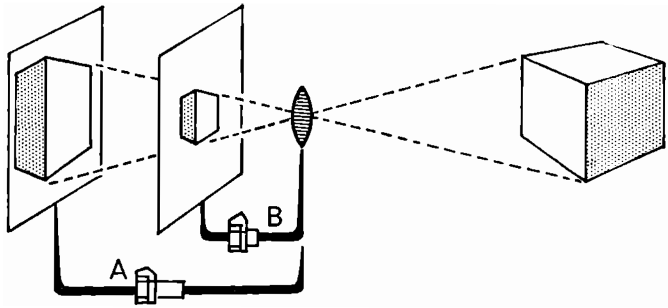
* For correct perspective at 25 cm or 10 inches viewing distance.

Here any relationship between focal length, magnification and viewing distance breaks down completely. As shown in Table II on page 33, the enlargement and final print size should decrease with longer focus lenses, for a correct perspective effect at 25 cm viewing distance; conversely the required viewing distance for a standard size print – for instance 13 × 18 cm – should increase with the greater focal lengths. In fact enlargements from miniature negatives tend to be made to more or less the same print formats and the pictures viewed from roughly the same distance irrespectively of the camera lens employed.

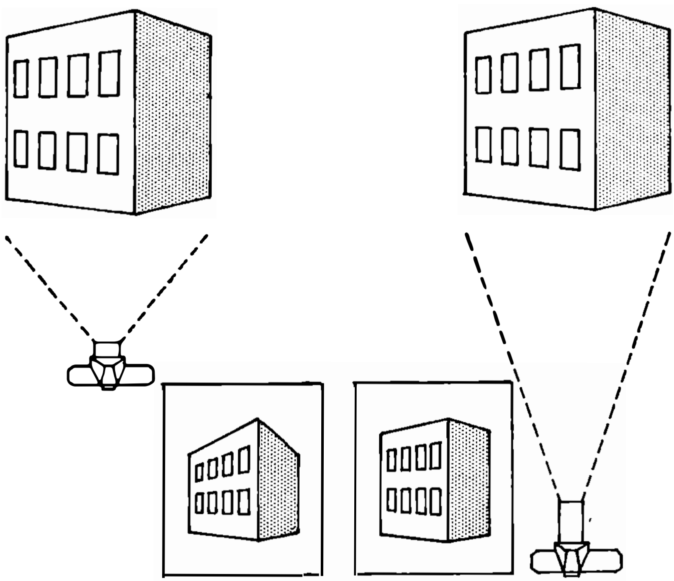
Obviously it would not be logical to stick to the correct magnification and viewing distance with the longer focal lengths; the required final print size (or viewing distance for a given print format) would, as indicated by Table II, be absurd. This is why telephoto pictures show their curiously flattened perspective; we look at them from far too close. At the correct viewing distance the perspective once more becomes natural. Thus the final print size of a 24 × 36 mm negative taken with a 500 mm lens ought to be about 12 × 18 mm for viewing at 25 cm. We would see the same perspective effect if we looked at an area of similar size in a 5 times enlargement to about 13 × 18 cm or 5 × 7 inches from a negative taken with a 50 mm lens–or even at a 1.2 × 1.8 cm or ½ × ¾ inch area of a 12 times enlargement of a negative with a 21 mm lens.

We simply have to accept the fact that we cannot achieve the realism of correct perspective with telephoto views. Fortunately this matters less in practice than might seem: long-focus lenses are most frequently used for purposes where optical access to distant subjects is much more important than their correct perspective in the picture. This applies especially to telephotography in industrial, military and similar fields. And where extreme long-focus lenses are used for pictorial purposes, the appeal of the picture is frequently just this unusual perspective view.

By similar arguments we can say that most people tend to look at wide angle pictures from too far away, or not enlarge the negatives sufficiently. That then leads to the exaggerated wide-angle perspective already mentioned. This is curable by simply adjusting the magnification and final print size to the appropriate relationship for correct



From a given viewpoint a camera with a long focus lens A produces a larger image than a camera with a short focus lens B, but the perspective of the two is identical.



If however the camera with the short focus lens (*left*) is brought nearer to depict the object at the same scale as the camera with the long focus lens from farther away (*right*), the perspective effects will be noticeably different.

perspective. It incidentally also leads to a new way of looking at photographs: owing to the increased angle of view which the whole photograph subtends at the eye we can no longer take it in all at one glance. The eye has to roam over the image – much as we scan a real scene in front of us.

This indeed greatly increases the realism of an enlargement from a wide-angle view. It is the reasoning behind wide-screen motion picture projection and we can arrive at similar conditions by projecting a colour transparency taken with a wide-angle lens on a big screen and sitting sufficiently closely in front of it. This realism of perspective becomes equally impressive with giant enlargements of negatives taken with a wide-angle lens and used, for instance, as photo murals.

PSYCHOLOGICAL ASPECTS OF ENLARGING

So when we look at a photograph we see the objects in the picture in their correct perspective relationship at one particular viewing distance. In fact it can often be observed that the photograph gains a sudden realism as we bring it nearer to, or farther away from, our eyes. This "jumping to life" is particularly pronounced where the picture shows familiar objects of different sizes and at different distances, such as buildings, street scenes etc.

While it is not always feasible, as explained, to insist on the correct viewing distance for the appropriate perspective effect, requirements are fortunately not quite so critical in practice. The rules outlined above for viewing distance and magnification take care merely of the difference between the eye and the camera when the two are considered simply as optical instruments.

There are certain other psychological factors involved as well, which must be mentioned briefly since they have a bearing on the importance of enlarging in the photographic process.

Vision in three dimensions consists of more than the production of a two-dimensional image on the retina of the eye, and the conversion of this by the mind into consciousness of the external world. A supplementary process going on at the same time tends to interpret objects seen in terms of everyday experience. This process in part compensates for

perspective foreshortening and exaggeration. When we happen to see a tree in the distance we get an impression of its actual size in spite of the relatively small scale on which we perceive it.

Such a rearrangement of visual values can be reproduced in a picture, and the more it is present, the more impressive the pictorial effect is likely to be.

This psychological function is largely responsible for the fact that big prints appear much more true to life than small ones, and that they tend to assume a pictorial aspect which is by no means as obvious in a smaller print from the same negative.

At the same time the surface structure of the objects portrayed is much more readily visible in a big enlargement. Details appear so much more clearly, that the result seems truer to the original from every point of view. The texture of fabrics like wool or silk or fur, materials like glass or metal, and even the human skin appear so perfectly reproduced with suitable enlargement, that we may feel that we only have to stretch out a hand towards the surface of the image to touch and feel the texture of the original material.

BIG ENLARGEMENTS AND LARGE NEGATIVES

The pictorialist, and also the professional photographer who has to decide which size of camera to take for an assignment, may now be worried by a perfectly natural question. Is it possible to get the same image effect from an appreciably enlarged miniature negative and a slightly enlarged bigger negative – or even a contact print from a really large format camera?

(We are for the moment sidestepping the issue of image quality and definition dealt with on page 56; in practice this issue is also weighed when considering the question we have just put.)

We really have two questions here, for miniature and larger negatives, and their cameras, differ only in externals. We are concerned with the different focal lengths of their lenses.

So the first question is: can the small negative taken with a short focus lens be enlarged so that the increased dimensions of the image will cause every image point to coincide

with the corresponding image point in a print of larger size from a long focus lens?

From the points already considered on page 29 we can answer this question in the affirmative. If the same viewpoint is chosen, exposures made are independent of the focal length of the camera lens. Suitable enlargement of a negative taken with the shorter focus lens will produce a print identical in perspective with a bigger negative enlarged to the same image scale.

The second question matters if the enlarging process is to be used to its best capabilities. Can identical prints be produced by using a longer-focus lens than usual on the camera, and by enlarging—to the appropriate scale—a portion only of the original negative taken with the normal focal length of lens?

Note that we have here dropped the condition of identical camera viewpoints, and are assuming only an identical image scale for the main subject in the picture. So the question really is: is it better to enlarge the image in the camera by appropriate selection of the focal length, or by the appropriate degree of enlargement when making the print?

Here the answer follows at least in part from the considerations of perspective already discussed, as well as from the photographer's normal approach to his subject. It is a common rule to get the camera as close to the subject as possible in order to fill the frame – in other words get the largest image possible in the negative area. To do this with a short-focus lens the camera has to come closer to the subject than with a long-focus lens. The different subject distances and camera viewpoints necessarily lead to a different image perspective. The resulting pictures will not be similar, and no degree of enlargement will make the print from the short-focus camera coincide over all its image points with that taken with a longer-focus lens from further away.

The choice between the alternatives just stated is therefore one of perspective.

When working with a whole set of interchangeable lenses for the same negative size the degree of enlargement enters into it only in so far as it has to be matched to a natural perspective at a standard viewing distance for a given print size.

In practice negatives taken with a short-focus lens tend to be insufficiently enlarged for natural viewing (see Table II on page 33) and hence show exaggerated perspective. This is another way of saying that with a short focus lens we are likely to go too close to the subject. The prominent perspective, making objects near the camera relatively too large and those at a distance relatively too small, can only be overcome by making the print very large or looking at it from very close.

So for normal perspective it is better to move farther away from the subject and either use a lens of longer focal length or enlarge the negative more later on. Provided the focal length of the lens is not excessively long, the degree of perspective flattening obtained is generally less disturbing than the exaggerated perspective of too near a camera viewpoint.

DEPTH OF FIELD AND FOCAL LENGTH

Let us get back once more to the first question posed on page 37 and put it in a slightly different way. Would a print of a given format obtained from a small negative taken with a short-focus lens correspond to a print of the same size enlarged from a bigger negative taken with a correspondingly longer-focus lens?

Here the camera viewpoint is assumed to be the same. So we can go straight back to Table I on page 32 to see that the perspective of the images in the two prints would be identical.

The use of a smaller negative results however in a number of other significant advantages.

The great popularity of the miniature camera is due not only to its obviously smaller size and greater film economy, but also to the greater depth of field obtained with a lens of shorter focus.

By depth of field we mean the region of acceptable sharpness in front of and behind the subject plane on which the camera is focused.

Objects or object planes at the distance on which the camera is focused are obviously sharpest. But the sharpness of objects falls off gradually both at greater and at nearer distances before the image on the film becomes noticeably unsharp.

This notion of "noticeably" is subject to an arbitrary standard, based on what the eye still sees as sharp on a print viewed at the right distance for correct perspective. The rate at which the sharpness falls off depends however on the focal length of the lens and on the lens aperture. Short-focus lenses at a given aperture yield images with a greater zone of sharpness or depth of field than long-focus lenses, while a large aperture gives less depth of field than a small one.

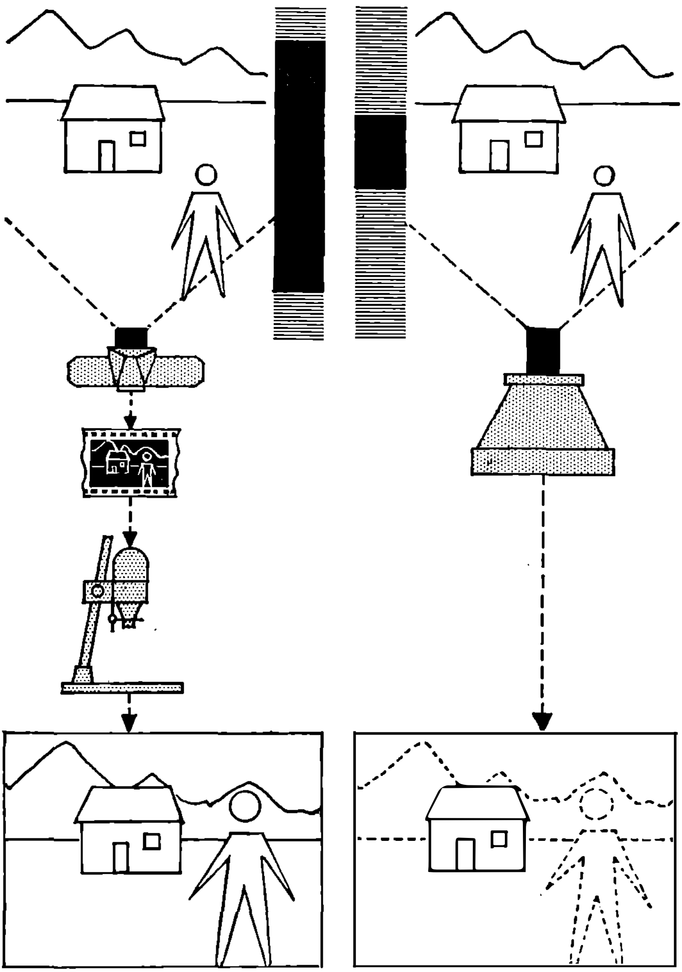
This difference in the spread of image sharpness is shown by a comparison example in Table III below. So an enlargement from say a 24 × 36 mm negative taken with a 50 mm lens will show appreciably greater depth of field than an enlargement from a 4 × 5 inch negative taken with a 150 mm lens, *even if both are enlarged to the same final print size* (as given in Table I on page 32) *and viewed at the right distance for correct perspective.*

III – DEPTH OF FIELD AND FOCAL LENGTH

Focused Distance		*Approx. Overall Depth at f2·8*	
Feet	*Metres*	*50 mm Lens 24 × 36 mm Negative*	*150 mm Lens 4 × 5 inch Negative*
3½	1	9 cm (3½ in.)	3 cm (1¼ in.)
5	1·5	18 cm (7 in.)	6 cm (2¼ in.)
10	3	70 cm (28 in.)	22 cm (9 in.)
50	15	2400 cm (960 in.)	530 cm (210 in.)

This difference is marked already at near subject distances; it becomes appreciably greater with more distant objects. Thus the overall depth with a 50 mm lens focused on 3½ feet or 1 metre is three times as great with a 150 mm lens; at 15 metres or 50 feet the depth with the shorter focus lens is already nearly five times as great. To obtain a similar depth with the long focus lens it would be necessary to stop down very considerably and so lose the advantages of the speed of a large-aperture lens. This alone makes the miniature camera and its smaller negative size more versatile for dealing with subjects in poor light (and miniature camera

FOCAL LENGTH AND DEPTH OF FIELD



A small camera with a short focus lens (*left*) produces a small image but with great depth of field, even when the negative is enlarged. A large camera with a longer focus lens yields a larger picture directly and – if the camera distance was the same – of the same perspective. In this case however the depth of field is greatly reduced (*right*).

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lenses are more easily and cheaply produced with large apertures).

It is an advantage which is only partly lost by the greater graininess due to the higher degree of enlargement of the miniature negative.

The Quality of the Negative

Since the negative is an intermediate stage in the production of a positive print, the quality of the latter depends greatly on the qualities of the negative itself. In other words, no enlargement can bring out more in image and tone detail than is already there in the negative. The important factors contributing to negative quality are sharpness, grain size and gradation. Let us look at these in turn.

DEFINITION AND VISUAL ACUITY

First of all, we can make sharp enlargements only from a negative image which is sharp in detail. The term "sharp" is however very vague; to compare different "sharpnesses" we therefore need some numerical scale.

There are several approaches to this. Let us first consider sharpness from the viewpoint of the human eye, on the assumption that a photograph need not show more detail than the eye itself would perceive. (For technical or scientific photographs, or where measurements have to be made on prints, this condition does not apply and stricter as well as more extensive standards of definition become necessary.)

To link up the power of detail perception or acuity of the eye with photography it is necessary to use the rather unfamiliar conception of a luminous circle which can be altered in diameter. By placing such a circle at a specified distance from the eye, it will appear as a surface when it is fairly large. But as its diameter is reduced it reaches a stage where the eye no longer sees a circular area, but a minute point. Further reduction of the diameter of the luminous circle will not reduce the apparent size of the point seen.

The eye therefore has a definite limit to its acuity below which it cannot perceive relative sizes. This limit is found by measuring the angle the luminous disc subtends at the eye at the moment when it ceases to appear as a circle and becomes a point of light instead. Scientific tests have established that under average circumstances the limit of visual acuity corresponds to an angle of 1 minute of arc. In practice

this means a luminous circle 0·1 mm or 1/250 inch in diameter when viewed at a distance of 25 cm or 10 inches. A circle of this diameter is also known as the limiting circle of confusion.

Thus if two points at this distance from the eye are less than 0·1 mm apart, the eye will fail to separate them and they will appear as a single point. So we can postulate as a visual standard of image sharpness in a photograph a circle of confusion (or lack of resolution) which does not exceed 0·1 mm when viewed at 25 cm or 10 inches.

It seems strange here to accept some lack of resolution, since we have already stated that sharpness is essential in a negative to be enlarged. But since the human eye has a limit to its acuity, we might expect similar considerations to apply to lenses.

THE DEFINITION OF LENSES

Camera lenses do in fact record object points not as perfect image points, but as minute discs. As a luminous circle in front of the camera is gradually reduced in size, the equivalent luminous circle in the image plane does not contract indefinitely. The minimum size of the image disc corresponding to an object point is governed by a number of factors, the most important of which in practice are the residual aberrations in the lens. This is the lens's limitation equivalent to that of the human eye in failing to resolve small detail at a great distance.

While this is not the place to go into details of lens aberrations and their variations, we can be satisfied if the performance of the lens is at least as good as that of the eye itself. Thus if we are dealing with large negatives and look only at contact prints made from them, a lens which produces an image with a limiting circle of confusion of 0·1 mm or 1/250 inch is adequate. But if the negative is small and has to be enlarged for a positive print, a very much higher standard of sharpness is essential. For this reason it is more convenient to consider resolving power in terms of the final positive image and the camera lens.

Thinking in terms of perspective effect, we can say that the circle of confusion must not be greater than 0·1 mm on the positive image when viewed at 25 cm. For a normal

lens (i.e. "normal" for the negative size) this is equivalent to saying that the circle of confusion must not exceed 1/2500 of the focal length of the lens. In this case, increasing size in the enlargement would simply imply that it is viewed from a greater distance for the most natural perspective, and the image will appear satisfactorily sharp at this distance. As the limiting size of an image point is enlarged in the print, the viewing distance increases proportionally and the constant relationship between the dimensions of the two is not altered.

Two cases where these calculations do not apply are:

(a) Critical scientific work or where exact measurements have to be taken from enlargements; and

(b) Interchangeable lenses of different focal lengths used on the same camera. Here we have to assume that the enlargements are viewed at the same distance irrespective of the focal length of the lens employed (and hence of any perspective considerations). The limiting circle of confusion is thus set by the camera lens of normal focal length and must be the same in absolute measurements – not relative to the focal length – for all the other lenses.

The majority of present-day camera lenses are capable of producing images of adequate definition to satisfy the above conditions. To that extent any further consideration of lens performance is somewhat academic. If the lens performance is inadequate, we can only get a better camera lens; we cannot improve such a negative in the enlarging process. At the best we can put up with lower degrees of enlargement and look at the prints from farther away than we should for correct perspective effects. This is in effect what the amateur owning a very cheap camera does, when he sticks little prints – nearly always below postcard size – into his album.

ACUTANCE AND CONTRAST

Before we leave the subject of optical sharpness we must briefly consider two further implications of visual acuity. The first is concerned with conditions that make us see an image as sharp – and which we shall meet again when considering the definition of films.

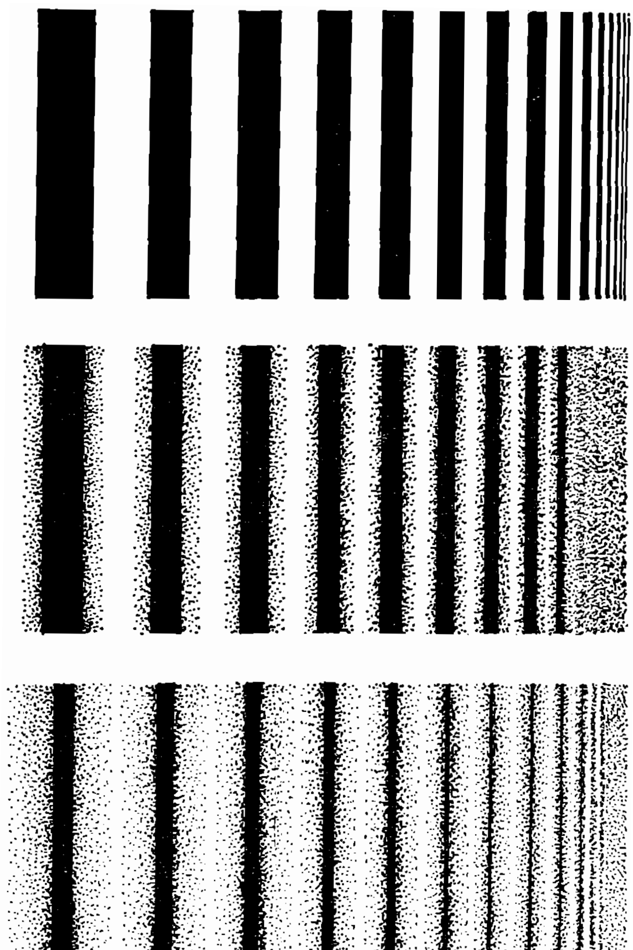
We have referred to the visual acuity of the eye in terms of the smallest detail it can separate or resolve at a given distance. For many years the resolving power of lenses – and also of films – used to be measured by photographing a test object on a reduced scale. This object or target consisted of sets of lines of decreasing thickness separated by spaces equal to the line thickness. The test photograph was examined under magnification to determine the finest set of lines which could be individually distinguished – i.e. the largest number of lines per millimetre. This number was quoted as the resolving power of the lens or film.

Visual sharpness depends however not only on the fineness of detail that can be distinguished in a resolution test, but also on the contrast of that detail. What matters in the image of the resolution test object is not only the number of lines separated per millimetre, but also the abruptness of the transition from black line to white space at the edge of every black line. This edge sharpness is particularly influenced by certain characteristics of the negative film (page 54).

So an image of high resolution but low edge sharpness may well look less sharp than an image of high edge sharpness but lower resolution. This difference becomes all the more prominent when we view such an image – for example in the form of an enlargement – from a greater distance: we may then well fail to appreciate the resolution limit (because it falls below the limit of the visual acuity of the eye), but we always remain aware of the image contrast and edge sharpness.

For this reason modern assessments of image quality take into account both resolution and the image contrast at which this resolution is obtained. (We can say approximately that reduced edge sharpness leads to reduced contrast at higher resolution levels.)

This relationship is expressed in a graph which plots spatial frequency (lines per mm.) against a factor which is related to image contrast. This graph is known under various terms like modulation transfer function, contrast transfer function or optical transfer function. Such a function is more complex and cannot be expressed by a simple number like resolving power. However, it can cover the whole reproduction process from the original subject to the final enlargement, and indeed even the visual appearance of the enlarged image.



In a photograph of a perfectly sharp test target (*top*), the lines in the image invariably spread, but can do so in two ways. As shown *centre*, the transition from black to white may still be fairly abrupt, corresponding to high acutance, but not necessarily high resolution. In the second case (*bottom*) a more gradual transition from a solid core of the black lines to the white intervals corresponds to lower contrast and lower acutance, but – paradoxically – sometimes higher resolution as even comparatively fine lines are still distinct.

It thus takes into account detail reproduction characteristics not only of the camera lens and the film, but also of the enlarging lens, the enlarging paper and – if wanted – the visual acuity of the observer.

What is significant from our point of view is that in terms of contrast transfer and hence of visual sharpness of an enlargement we have to pay attention during the enlarging process to all the factors which influence contrast and definition. These cover enlarger steadiness, enlarging lens quality, image brilliance, contrast and even the choice of enlarging paper surface. These factors will be discussed in due course as they arise.

LACK OF SHARPNESS DUE TO THE SUBJECT

A second consideration of image sharpness in a negative is concerned with the contribution of the subject itself. We have already touched on one aspect of subject unsharpness: depth of field (page 40). A second cause for lack of perfect definition in a negative is the movement of objects in the scene during the exposure. Obviously if an object moves through a sufficient distance while the shutter is open, this distance is resolved by the lens, and the negative will record that object as visibly unsharp.

The factor governing this lack of sharpness is the same as postulated initially for visual acuity: the limiting circle of confusion. This is indeed the standard of sharpness on which depth of field calculations are based. Equally the movement of an image on the film during exposure must be smaller than 1/2500 of the focal length (page 45) if this image is to appear sharp. Tables quoting longest permissible exposure times for action subjects are based on this consideration.

In practice the limiting circle of confusion for depth of field purposes is often taken as appreciably larger, especially with less expensive cameras. The reason is in part the lower lens performance and degree of enlargement to be expected from such negatives (page 44) but also the fact that the main emphasis in a picture is on its sharpest part and slight shifts in the boundary of the depth of field zone are less noticeable.

In the case of subject movement a certain deliberate unsharpness may improve the pictorial effect. For example

shots of a waterfall, exposed with a sufficiently fast shutter speed to show every drop sharply, look too frozen. Similarly, pictures of dancers and athletes in rapid motion may gain impact by a certain amount of blurring in their outlines.

One kind of movement blur is however always disturbing: unsharpness due to camera shake. This degrades the definition of the whole negative, but often remains unnoticed in small enlargements, especially when these are viewed from farther away then they should be for correct perspective. At higher magnifications and correct viewing distances there is no way of getting rid of this type of unsharpness – we simply have to discard the negative. The equivalent of camera shake however also arises during the enlarging process, if the enlarger is not sufficiently rigid and vibrates during the exposure of the print (page 166).

GRAIN AND THE FILM

If we look at a piece of photographic film through a high-power microscope, the first thing that we observe is that the emulsion layer is far from homogeneous. It consists in fact of innumerable very tiny crystals or grains of the light-sensitive silver salt. These grains correspond to the tiny black grains of metallic silver formed on development. At high magnification – either when viewed through a microscope or in a big enlargement – this grainy structure of the image becomes noticeable and affects the image in several ways.

The first is the disturbing visual inhomogeneity of the image tones. This is graininess proper and is the result of what is known as granularity – the grainy structure of the photographic image itself which can be evaluated in measurable terms. In practical photographic terminology we use granularity mainly in connection with a negative, while graininess refers mainly to the print. Both terms have in fact a different meaning although they are often used in the same sense.

The graininess of an enlarged image depends thus both on the granularity of the negative and on conditions which accentuate or subdue this granularity in the print. To reduce the subjective impression of graininess we therefore have to look at both sets of conditions.

The granularity of the negative depends on the emulsion

itself, the exposure and on processing. There are thus fine-grain and coarser-grain films. Generally fine-grain emulsions are slower and fast emulsions have coarser grain. Increasing the negative exposure beyond the minimum required for good tone reproduction also increases the granularity. Finally the developer has a definite effect on granularity (page 59).

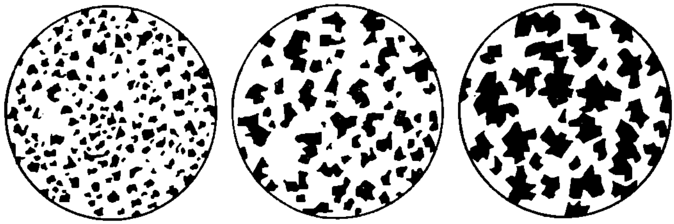
The graininess of the print for a given negative granularity is influenced by the degree of enlargement, the enlarging conditions (type of enlarger and contrast and surface structure of the paper), and the conditions of viewing the print.

Obviously, the higher the degree of enlargement, the more visible the graininess becomes in the print. This is one of the main factors operating against small negative sizes (and one reason in favour of large negative formats in professional photography). As modern negative emulsions however yield very much finer grain than corresponding materials 20 or 30 years ago, negative grain is far less serious a problem nowadays than it used to be in the early days of miniature cameras.

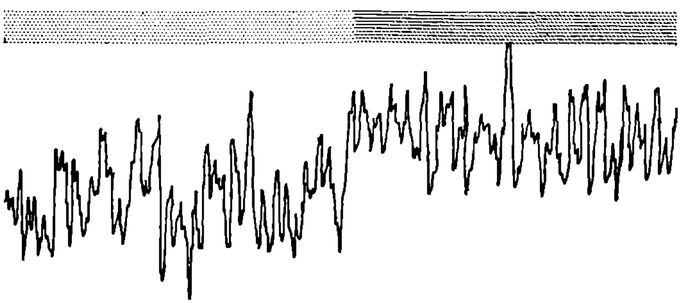
Enlarging conditions determine graininess mainly in terms of the contrast of the image. Thus a print will appear grainier if the negative is enlarged on a more contrasty paper grade (page 77), or with a condenser enlarger and highly directional illumination (page 126) which increases image contrast.

Generally, controlling contrast is not much use to control graininess, as the choice of the paper is determined by the contrast of the negative to obtain the best relationship between the tone reproduction of the print and the tone scale of the original scene. Graininess in a print can however be suppressed somewhat by choosing a paper with a matt or, still more, a grained surface structure. Any measure which reduces print sharpness, such as soft focus lenses and diffused enlarger lighting will also reduce graininess.

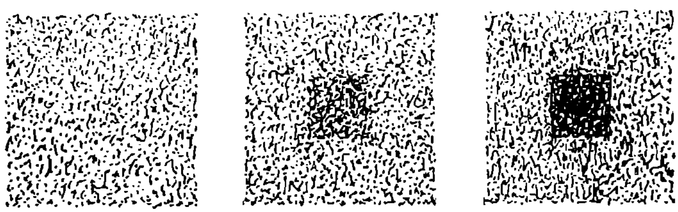
The conditions of viewing the print matter, since graininess will disappear if an enlargement is viewed from a sufficiently great distance. Generally, graininess tends to decrease more with greater viewing distance than it increases with the degree of enlargement necessary for correct perspective at such a viewing distance. This is because the eye is aware of the inhomogeneity of the image due to



High-speed negative emulsions (*right*) usually have larger individual silver grains than slower emulsions (*left*). In every case there is however still a range of grain sizes; it is the average grain size which is characteristic of the film.



If we trace across a boundary of two density levels in a developed film with a micro-densitometer, we can detect this boundary only by the change in average density level. Individual density changes, as the micro densitometer scans single grains, may be greater than the actual difference in average density levels.



Graininess therefore obscures subject detail not only by lowering resolution, but also by its "noise" effect. If therefore the contrast between a small image detail and its surroundings is too small, the detail becomes invisible (*left*). With increasing contrast the detail becomes progressively more distinct (*centre* and *right*) against the still "noisy" – i.e. grainy – background.

granularity before it can see individual grains as such. This appreciation of inhomogeneity as a background to resolvable detail decreases at greater viewing distances.

GRAIN AND RESOLUTION

If we consider the resolving power of an emulsion at a given image contrast (avoiding for the moment the complexities of transfer functions – page 46) we arrive at an obvious way in which grain influences resolving power. If the lines of a test object at the limit of the resolving power of the lens are so close together on the film that their separation is smaller than the grain size, the negative would obviously be unable to separate these lines. Each grain is completely reduced to metallic silver during development, and the grain structure in this case would be coarser than the image detail.

In fact even with emulsions containing the coarsest grains, the single grain size is well below the limit of image resolution, having an average diameter between 0·5 and 5 microns. The grains are however not distributed regularly in an emulsion, but scattered at random. This means that in certain places the grains appear to congregate in clumps, and at others they appear to be relatively sparse. This is enhanced by the fact that the grains are also distributed in depth through the emulsion. So a clump is due not only to a spreading of image grains during development (which does occur) but also to a partial superimposition of grain silhouettes in different planes of the emulsion layer. It is this irregular distribution of the grains which gives photographs their grainy appearance.

The size of these grain groups is one factor determining the resolving power of the emulsion. The smaller the grains, the smaller will also be the clumps of grains and the higher the resolution; the lower will be the granularity.

Further, the uneven distribution of the grain structure in an emulsion also tends to mask image detail which is considerably larger than the grain diameter, even taking into account clumping phenomena. This is because in an image we are dealing with details of different density. This density – a measure of light stopping power – is a function of the grain concentration. Even in an area of uniform tone this grain concentration can vary appreciably from spot to

spot. The average variation is greater, the smaller the spots we are considering. If we take very small spots – say of 10 microns (0·01 mm.) in diameter at random points within a "uniform" tone area, the average light stopping power within several such spots might vary by a factor of, say, 3:1.

Let us now stipulate another image tone of twice the average light stopping power of the first one. In this tone an image detail 10 microns in diameter might have an average light stopping power which is within the statistical spread of the densities of our spot samples in the first image tone. In other words, although this detail might be 10 times as large as a grain diameter, its tone difference is masked by the random variations in grain distribution in the image. We simply do not know whether an observed difference in light stopping power between two image spots is due to a genuine tone difference of detail or to blind chance.

To resolve such tone differences we thus have to decrease the element of chance. We can either increase the difference in the average density of the two tones (i.e. aim at greater contrast). Or we can increase the size of the detail we are considering, to a point where the tone difference between this detail and its surroundings is greater than the variation of average light stopping powers. That of course means reducing our demands on resolution. This is incidentally one reason why resolution depends on contrast.

RESOLUTION AND ACUTANCE

The fineness of the silver grain is not the only factor determining the visual quality of the picture. When a light beam reaches a photographic layer it is scattered by the grains in the emulsion. It may thus reach areas adjacent to the image point which that light beam forms. As a result the image spreads laterally, and very fine image details close together may easily fuse into each other and be no longer resolved.

Even where such scattering or irradiation does not actually obscure image detail, it still causes some blurring of image outlines. The change in density along the line of separation between a light area and a dark area will not be so abrupt and sharp as desirable to produce a crisp image, but more or less fuzzy. The abruptness of the change in density along such an outline between the light and the dark area determines the edge sharpness of the image. On the film this

edge sharpness can be measured; its mathematical value is known as acutance. We have met this kind of sharpness criterion before (page 46) and can now see that it depends, for our purposes, primarily on the characteristics of the negative film.

The thinner the film emulsion, the less this scattering and the greater the acutance of the image. Modern negative materials, especially for miniature cameras, therefore have thin emulsion layers of about 12 to 17 microns (0·012 to 0·017 mm or 0·0005 to 0·0007 inch) thick. Special high-acutance films – usually the slower miniature emulsions – have even thinner layers between 8 and 10 microns (0·0003 and 0·0004 inch) in thickness.

This contrasts notably with high-speed roll films for amateur use, having two emulsion layers. The top layer is highly sensitive, and is coated on top of one of lower sensitivity. The combined action of these two emulsions increases the exposure latitude of the film. If for instance the exposure is such as to over-expose the upper emulsion – which would normally lead to a flat and inferior negative – the lower and less sensitive emulsion takes over and ensures a usable and printable negative.

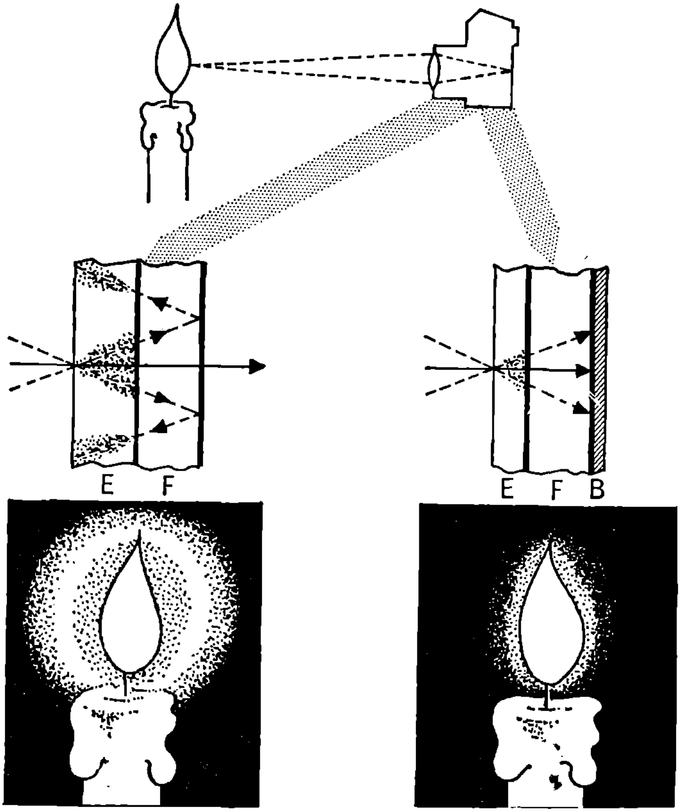
From the point of view of image sharpness however such double-coated films are far from ideal. The thick double-coated layers, with a total thickness of 20 to 25 microns (0·0008 to 0·001 inch) enhance the scattering of light, and the image in the bottom layer is more or less blurred. Where small enlargements only are required this is not particularly important and the loss of definition is hardly noticeable.

The justification of double coating fast films is that their graininess already leads to a greater loss of resolution than occasioned by the double coating. However, where great enlargements are required, a double-coated or even thick coated film is not suitable.

While double coating increases the exposure latitude, films with a single or thin coating have a comparatively limited latitude. This raises few problems for the modern photographer, because he has at his disposal automatic cameras or at least simple but reliable exposure meters.

In addition to irradiation or light scatter a related phenomenon also reduces image definition. This is halation, and is due to the reflection of light rays by the back of the film

IRRADIATION AND HALATION



When light from a bright object strikes the film, light rays are scattered within the emulsion layer E (*left*) by reflection from individual grains; as a result the image spreads. This is irradiation. In addition rays penetrating through the film base F may be reflected from the back of the film and re-enter the emulsion, producing a halo outline of bright subject points – hence the term halation. Both effects are particularly pronounced with thick-emulsion films.

With a thin emulsion film (*right*) the light spread and hence irradiation is greatly reduced. An anti-halation backing layer B can absorb rays reaching the back of the film base F and so largely eliminate halation. (For clarity the emulsion layers are shown greatly exaggerated in thickness compared with the film base; in fact, the film base is about ten times as thick as the average emulsion layer.)

base after their passage through the emulsion layer and the base. This reflected light exposes more silver halide grains in the emulsion, forming a hazy halo surrounding every image point. It is particularly noticeable in the neighbourhood of brilliant image details. Halation can be restricted by various methods, such as dyeing the film base, or coating a light absorbing layer either between the emulsion and the base or at the back of the base.

THE LIMIT OF ENLARGEMENT

The resolution of the negative image, considered for the sake of simplicity as a figure in lines per mm. under specified conditions, determines also the degree to which we can usefully enlarge a negative. This depends much more on the format and quality of the negative than on the final print size we want. For if we consider merely enlargements of different magnification from the same negative, we would look at the bigger prints from farther away, so that the image detail we can perceive would be the same. In considering limiting enlargement we must instead turn to the detail content of the picture.

At a viewing distance of 25 cm the eye can resolve image points of a minimum size of 0·1 mm. A viewing distance of 25 cm for correct perspective corresponds to a 5 diameter enlargement from a 24 × 36 mm negative taken with a 50 mm lens (page 32). So if the negative resolves image details at least 20 microns (0·02 mm) large – and no definition is lost in the enlarging process – we should see the same amount of detail in looking at the print that we would see when observing the original scene.

This standard of resolution, corresponding to 50 lines per mm., is well within the scope of even comparatively coarse-grained 35 mm. films. So there should be no difficulty in enlarging 24 × 36 mm. negatives to any degree without loss of visual detail.

An 18 × 24 mm. negative, made in a camera with a 30 mm. lens, would need around 8 to 9 diameters of enlargement for a print of natural perspective at 25 cm viewing distance. Here the required negative resolution goes up to 85 lines per mm. – still within the range of fine-grain to medium-speed films. Similar conditions still hold for a 10 × 14 or 13 × 17 mm. ultra-miniature negative taken

with a 25 mm lens: a fine grain film generally yields the required resolution figure of around 100 lines per millimetre.

Conditions become considerably more critical with the smallest ultra-miniature negatives of 8 × 11 mm, using a 15 mm lens. The required degree of enlargement (see Table I on page 32) is over 16 times and only high-acutance films of the finest grain can get anywhere near the now required resolution of 160 to 170 lines per millimetre.

If we expose such a negative on a film of lower resolution we lose information detail. This means that an enlargement of the correct magnification for natural perspective will show less detail than we can perceive. Some of the magnification will be what microscopists call "empty" magnification. In practical terms we might for instance by looking at a landscape be able to recognise not only individual trees in the middle distance, but also their main branches; not only houses across the road, but also detail of their brickwork. The enlarged ultra-miniature image however will fail to show recognisable branches or bricks. This loss of resolution is quite independent of graininess, though the latter may also obtrude. We become aware of excessive enlargement of the negative.

This is one of the limitations of extremely small negative formats. We must either take ultra-miniature pictures on negative materials of extreme resolution, or be satisfied with comparatively smaller prints which we regard at a greater viewing distance than required for natural perspective (and put up with the loss of perspective impact). If the camera lens performance also falls short of the postulated definition standard, the possible degree of enlargement is further restricted.

This does not mean that enlargements from ultra-miniature negatives which do not satisfy this condition of resolution are useless. We become aware of the loss of image detail, but the picture can still be acceptable. Indeed we accept a greater loss of image detail when watching television. The image resolution with a 405-line television system corresponds to about 2 lines per mm at the correct viewing distance for natural perspective – compared with 10 lines per mm for the limit of visual acuity. With a 625-line system the resolution is a little better – about 3 lines

per mm. If we are near enough to the television screen to perceive the line structure of the image, we will in both cases see less detail than we could perceive in the original scene from the same viewpoint as the television camera.

The loss of image detail is generally least disturbing in close-up views and becomes more obvious in more distant scenes or images showing considerable subject texture. Nor is it irrelevant to consider that for many pictorial effects – soft focus and similar tricks etc. – we accept considerably less definition than the eye can appreciate. The fact remains, however, that for any work requiring high definition the ultra-miniature camera is inadequate.

FINE GRAIN FILMS AND FINE GRAIN DEVELOPMENT

During the first couple of decades after miniature cameras became popular – in fact up to the late 1940s – most miniature films had inconveniently high granularity. They required special fine grain development techniques and formulae to yield images of acceptable grain.

Such fine grain formulae, sometimes with extravagant ingredients of incompletely understood function, often appreciably reduced the effective speed of the film. So for development in these ultra fine grain developers the negative had to receive frequently 100 per cent or more extra exposure. This sacrifice in emulsion speed and the inconvenience, toxicity and occasionally very long development times involved in using some of the developers were regarded as a necessary evil because the only films capable of giving reasonably fine grain also had extremely low emulsion speeds.

Current negative materials, especially emulsions of miniature films, yield sufficiently fine grain even in more normal developers to make the former ultra-fine grain formulae with their inherent disadvantages largely obsolete. The only films which still yield negatives of sometimes disturbingly high granularity are ultra high-speed emulsions intended for extremely poor light conditions. There is however little sense in attempting to improve the granularity of such materials at the expense of their speed. That would merely bring them down to the level of the sensitivity of normal high-speed materials, which however yield appreciably finer grain with orthodox development. Instead,

ultra-speed films are often processed in maximum energy developers. These boost the speed up still further for extreme subject conditions where no other film and developer combination could yield an adequately exposed image. Under these circumstances the somewhat more prominent granularity simply has to be accepted.

For slow to medium speed, and even moderately high-speed, emulsions the choice of a developer is governed by the following factors:

(1) The developer should not produce excessive contrast – which would not only enhance granularity but also make the negative difficult to enlarge.

(2) The developer must preserve the original fine grain of the emulsion without tendency to favour agglomeration or clumping of grains.

(3) The developer should not reduce emulsion speed.

If the developer in addition tends to reduce granularity, this is of course a useful feature provided it is not obtained at the expense of other important factors.

With high-acutance films granularity is never a problem. To make the most of their definition qualities such films are however best developed in high-definition developers which counteract the film's tendency to high contrast, and further increase the image acutance.

FINE GRAIN DEVELOPERS

To satisfy the conditions listed above, most fine grain developers have two characteristics:

(1) A low development energy – usually achieved by a controlled pH, i.e. not too great alkalinity. This slows down the development rate, reducing the tendency to clumping, and ensures negatives of medium contrast and density.

(2) Fine grain developers often contain a mild solvent for silver halide. This also reduces the tendency to grain clumping and may even improve the grain size of the negative material itself. The solvent action should be mild, as otherwise exposed silver halide grains get dissolved before they have a chance of being developed, which leads to a loss of emulsion speed. For this reason formerly popular solvents like hypo and potassium thiocyanate are rarely used nowadays.

Sodium sulphite in concentrations up to around 10 per cent is still the most useful silver halide solvent in a developer.

Nowadays major photo-chemical manufacturers offer an adequate range of pre-packed negative developers meeting various fine grain, high acutance and other requirements, and few photographers bother to make up their own developers from published formulae – it is too cumbersome. The fine grain and high-definition developers in tables IV and V respectively are thus listed for basic interest rather than as a recommendation to prepare processing solutions from their individual chemicals.

Formula No. 1 is the classical MQ-borax combination which figures, with minor variations, among recommended developer formulae of nearly all film manufacturers.

IV – FINE GRAIN NEGATIVE DEVELOPERS

Ingredient	**1** *D76, ID11*	**2** *D23*	**3** *G207*	**4** *ID68*	**5** *M & B*	**6** *Focal*
Metol	2	7·5	2	—	—	—
Hydroquinone	5	—	—	5	—	—
DIEPPD*	—	—	—	—	—	20
Phenidone	—	—	—	0·2	—	—
Glycin	—	—	—	—	11·6	20
HYEOAP**	—	—	—	—	6	—
Sodium sulphite, anh.	100	100	100	100	100	100
Sodium carbonate, anh.	—	—	5·8	—	11·5	—
Borax	2	—	—	2	—	20
(or Kodalk)	(2)	—	—	—	—	(20)
Boric acid	—	—	—	1	—	—
Potassium bromide	—	—	2	1	—	—
Water to	1000	1000	1000	1000	1000	1000
Working dilution	—	—	—	—	—	1:7
Development time (min.) at 20°C (68°F)			8–10	8–10	6–10	12–15

All quantities in grams or (for water) ml.

* Diethyl paraphenylene diamine bisulphite (Genochrome, Activol No. 1).

** Hydroxyethyl-ortho-aminophenol.

Formulae Nos. 2 and 3 are based on metol and sodium sulphite to produce a soft working developer of moderate solvent activity; these formulae are more suitable for slower high-contrast fine grain films and for high-acutance emulsions if special high definition developers are not used. Formula No. 4 uses a combination of Phenidone and hydroquinone as the developing agents, but does not differ appreciably in activity or effect from No. 1. Formula No. 5 is the only one in this collection based on a less familiar developing agent. It is almost a super fine grain developer, but preserves the full emulsion speed of the film. This M & B formulation is similar to a well-known proprietary fine grain developer.

All these developers are used at the full working strength in which they are made up and a number of films can be developed in succession, the developer being either replenished or the development time increased to compensate for the loss of activity. Formula No. 6 differs from the others in being a concentrated stock solution which is diluted for use. The dilute developer is then discarded after every film.

High-definition developers are listed in Table V below. Their characteristic is a soft working developing agent such as metol at a low concentration with a relatively high concentration of alkali to maintain its activity.

V – HIGH DEFINITION NEGATIVE DEVELOPERS

Ingredient	**7** *W. Beutler*	**8** *FX 2* *G. W. Crawley*	**9** *FX 13* *G. W. Crawley*
Metol	5	0·25	0·5
Glycin	—	0·75	—
Sodium sulphite, anh.	25	3·5	40
Sodium carbonate, anh.	25	—	2·5
Potassium carbonate	—	7·5	—
Ilford Desensitol sol. (ml)	—	3·5	—
Potassium iodide 0·001% sol. (ml)	—	—	5
Water to	1000	1000	1000
Working dilution	1:10	—	—
Development time at 20°C (68°F), min.	7–10	15	10

Such a developer also gives rise to edge effects due to active developer diffusing from shadow areas in a negative to adjacent highlight areas and exhausted developer diffusing from highlight areas to adjacent shadow regions. At boundaries between light and dark negative areas this results in a darkening of the already dark area and a lightening (by retardation of development) on the lighter side of such a boundary. This leads to an increased edge contrast or acutance at such boundaries, enhancing the already high acutance of the film itself.

Such high-definition developers can only be used once and the working solution must be discarded after every film. They can however be made up as concentrated stock solutions; Formula No. 7 is given in the form of such a stock solution, and No. 8 could be made up similarly with all ingredients at ten times the indicated concentration, the working solution being diluted 1:10. Formula 9 could be made up at 2½ times the indicated strength and diluted accordingly.

AFTERTREATMENT OF GRAINY NEGATIVES

If excessive development has produced a hard negative with coarsened granularity some correction is often possible by aftertreatment of the negative itself. The method described below may also be used where it has been necessary to use an ultra speed emulsion with correspondingly coarse grain. It is however intended more as a standby for extreme cases, where other methods of subduing grain during enlarging are inadequate. (Chemical aftertreatment of negatives, especially in small formats, carries a certain risk of physical damage such as scratching during handling.)

First wash the negative thoroughly to remove all traces of hypo. Then bleach the image in the following bath:

10 – COPPER BLEACHING BATH

Copper sulphate, cryst.	4 ounces	100 grams
Sodium chloride (common salt)	4 ounces	100 grams
Sulphuric acid, 10%	10 ounces	250 ml
Water to	40 ounces	1000 ml

If concentrated sulphuric acid is used, take 1 ounce or 25 ml and pour slowly, while stirring, into about 15 ounces of water before adding the other ingredients. (Never pour water on top of the concentrated acid.)

After bleaching – until all trace of the black silver image has disappeared – wash the film until the image is pure white (with no bluish tinge), then redevelop in:

II – PARAPHENYLENE DIAMINE REDEVELOPER

Paraphenylene diamine (or DIEPPD*)	60 grains	3 grams
Sodium sulphite, anh.	1 ounce	25 grams
Water to	40 ounces	1000ml

* Diethyl paraphenylene diamine bisulphite (Genochrome, Activol No. 1). This substance is in fact preferable to paraphenylene diamine as it does not stain and is easy to handle.

Continue development until the image has developed right through the emulsion and is plainly visible from the back of the negative. At this point the image will appear exactly as it did before bleaching, but on placing it in normal acid fixing bath it will rapidly become lighter. The final resulting image is considerably softer than that of the original negative, and also finer in grain.

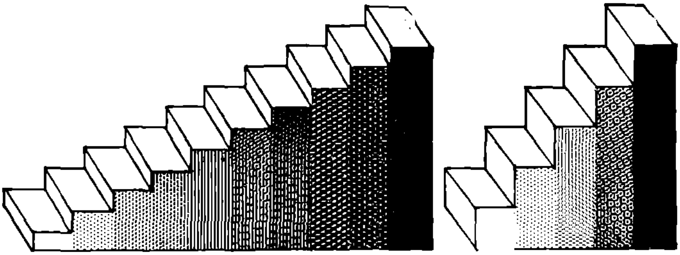
If the image should still prove too hard for convenient enlarging, the process can be repeated after a thorough wash to remove all traces of hypo from the emulsion.

NEGATIVE GRADATION

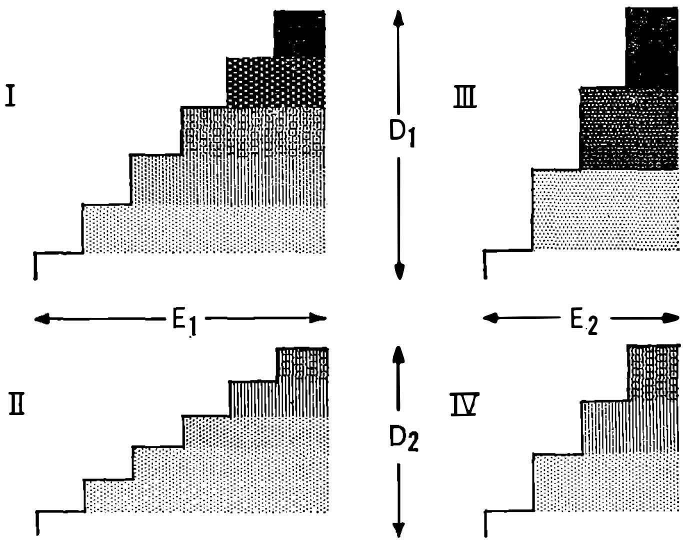
Gradation is the quality in the negative material which controls the manner in which the original subject brightness values are reproduced in different tones of grey in the negative. The gradation of the positive material in turn controls how these grey tones are reproduced as a range of tints from white to black on the print or enlargement.

The concept of gradation becomes clearer with a simple experiment. Cover up a strip of sensitive paper with a sheet of black paper and then expose sections of it in such a way that each section receives twice the exposure of the preceding one. After developing the exposed strip we get a scale of tones between full white and full black. This scale of tones will vary greatly in range according to the character of the paper on which it was made.

With many emulsions the fullest black possible is reached after very few sections of the strip have been exposed, so that the scale of tones is a very steep one. Emulsions of this

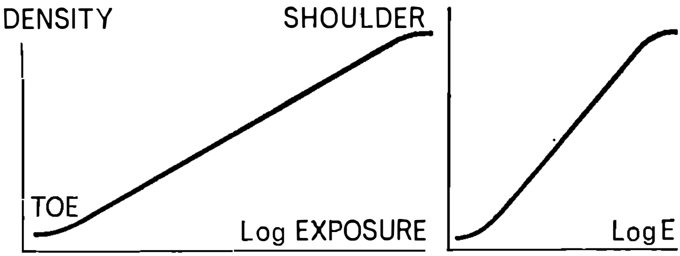


In a soft negative material, exposure changes build up image density only gradually (*left*). A more contrasty emulsion reaches full blackness in a much shorter exposure range – fewer but steeper steps between white and black (*right*).

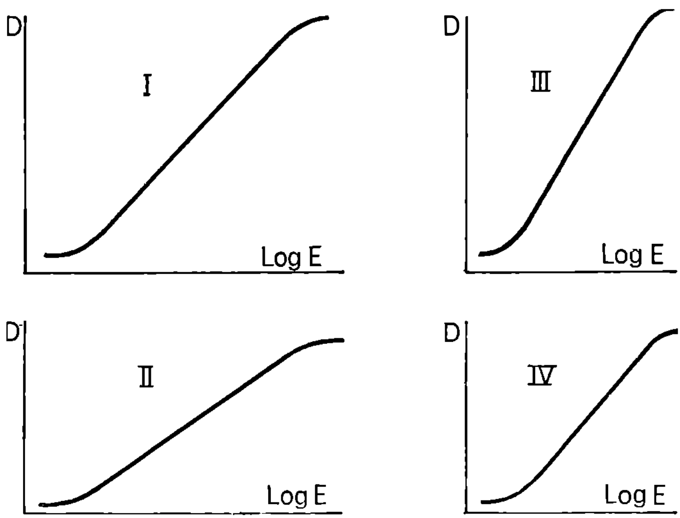


Gradation is concerned both with exposure range – the ratio of exposures for the film's minimum and maximum achievable densities – and density range, the maximum density obtainable. Thus staircases I and II have the same exposure range E_1, but II has a lower density range D_2. It can record subjects of the same brightness range but yields negatives of a lower contrast. Staircases I and III have the same density range D_1, but III has a shorter exposure range E_2 – so it cannot cope with as great a subject contrast, but yields contrasty negatives. Staircase IV has a short exposure range and a low density range.

CHARACTERISTIC CURVES



The characteristic curve of a negative emulsion is obtained by giving the film a series of known stepped exposures, and plotting the density (page 67) of the silver deposit produced after development for each exposure. The curve flattens at the bottom (the toe) and top (the shoulder), but essentially corresponds to the staircases shown opposite. Thus we can have a negative material of soft gradation (*left*) or of harder gradation (*right*).



These four curves again correspond to the four lower staircases on the opposite page. Thus curves I and III again have the same density range but different exposure ranges; curves I and II have the same exposure range but different density ranges. The longer the curve, the greater its exposure range, the higher the curve the greater its maximum density, and the steeper the curve the greater its contrast.

type have a hard gradation, or high contrast. Other papers may show a very long range of tones increasing in density before the fullest black is reached. In this case the emulsion has a soft gradation, or low contrast.

Between these two extremes is naturally a wide range of intermediate contrasts.

We can visualise this behaviour of emulsions graphically in the form of a staircase, where the height of the steps represents the difference in tone (photographically, in density) resulting from the step-by-step increase in exposure. The horizontal length of the steps corresponds to the exposure intervals. In this representation (page 64) a hard-gradation or contrasty material rises from white to black in a few rather high density steps, so that the total exposure ratio between white and black is comparatively low. A soft gradation material on the other hand takes a large number of shallow steps to go from white to black; accordingly the staircase is considerably longer (even if of the same height), representing a great exposure ratio between the extremes of tone.

When we deal with photographic papers for enlarging, such papers are in fact marketed in a range of contrasts and grades and labelled accordingly, going from soft through normal to hard and extra hard.

MAXIMUM DENSITY

If we make a similar experiment in strip exposures on a negative material, different films would show a further difference: the maximum black which an emulsion can produce varies appreciably in density between different makes and types of film. Some emulsions give exceedingly dense full blacks, while others are incapable of producing more than a medium density – or even quite a light grey.

When examining a film, we therefore have to consider two points:

(1) The manner in which the density increases from the minimum (virtually transparent film in the case of a negative material) to full black, and

(2) The density present in the fullest possible black.

These two factors are by no means the same. To appreciate the difference, let us look once more at our staircase. The

overall height to which such a staircase ascends corresponds to the maximum density of the full black given by the emulsion. This is adjusted by the emulsion chemist during manufacture and may also be influenced by development.

The staircase may moreover reach a given maximum height in a number of ways. The steps may either be shallow and numerous or deep and relatively few, whatever the height of the staircase itself may be. If the steps are deep and only a few of them are used, they will correspond to the few grey tones of a hard-contrast film. If they are shallow and numerous, they are equivalent to the soft contrast emulsion.

In a similar way, the actual negative images exposed in the camera may show few steps between their shadows and highest densities, in which case the image is hard. If a large number of steps appear, the emulsion is softer. This is true whether the maximum black of which the emulsion is capable is actually produced in the negative or not.

A film capable of producing a maximum black or very high density is by no means necessarily hard in gradation – the latter point is decided by the number and rate of increase in the middle tones. A soft-gradation emulsion has a large number of intermediate steps or tones between black and white (or transparent): where these middle tones are few in number and density increases suddenly, the emulsion is hard.

Similarly, a film of low maximum density is not necessarily soft in gradation, for again the latter is decided by the manner in which the middle tones are recorded.

CHARACTERISTIC CURVES

Physicists measuring the behaviour of photographic emulsions under conditions of exposure make a similar test of giving the material a series of exposure steps increasing by a constant factor. Such an exposure series is logarithmic: the intervals along the base of the "staircase" are proportional to the logarithm of the exposure time. When the densities of these steps are measured, this measurement is also logarithmic, for the density is proportional to the logarithm of the amount of silver produced by the exposure on development.

When the density is plotted against the logarithm of the exposure, we get a curve known as the characteristic curve

of the material. In this curve we can find again, even if in a slightly different form, all the parameters of the staircase considered before. Thus the maximum height of the curve indicates the density of the maximum black. The slope at which the curve rises up to this maximum density corresponds to the steepness of our staircase: a curve of high slope rising up strongly over a comparatively short logarithmic exposure range, corresponds to the steep staircase of few steps, and a flat curve rising up slowly – even if to a high maximum density – over a long range of exposure steps corresponds to a material of softer gradation.

The slope of the characteristic curve is in fact often used to describe the gradation of a photographic image. Its numerical value (the tangent of the angle of its steepness) is known as the gamma of the curve. Hence a high gamma corresponds to high contrast and a low gamma to low contrast.

We have so far assumed that the characteristic curve is a straight line rising more or less steeply to greater or lesser maximum densities. In fact the characteristic curves of photographic materials are straight only over their middle section. They flatten out near the top and also near the bottom. These regions are known as the shoulder and the toe of the curve respectively.

The gamma of the characteristic curve refers to the slope of its straight line portion. The lower slopes and hence softer gradation near the shoulder and the toe are significant when we consider tone reproduction and distortions of the extreme shadows and highlights of an image. We shall come back to that on page 102.

THE CHOICE OF NEGATIVE GRADATION

In theory we should choose a negative material of suitable gradation for the type of subject photographed. Thus low-contrast subjects – for instance aerial views or the reproduction of documents and drawings – would call for a film of hard gradation to compensate this lack in contrast and so make detail appear more distinctly in the picture. Similarly exposures made in conditions which produce flat contrast in the subject – dull weather, mist etc. – should really be made on a film with a relatively hard emulsion. Portraits and many other artificial light subjects, and also outdoor

views in brilliant light, which have a long range of tones and great brightness range would call for a soft gradation film to accommodate this tone range (see also page 64). Negative materials of such selected gradation, supported by correspondingly high- or low-contrast development, may in fact be chosen where the exposures are made on single sheet films or where the whole of a roll or miniature film is devoted to subjects of similar tone range.

In practice a roll of film from the camera of an amateur or even a professional feature or news photographer may cover a series of different exposures made under widely varying conditions of lighting and contrast. There the only feasible procedure is to aim at an average contrast in the negative which will suit the majority of the exposures on the film. We then select enlarging papers of appropriate contrast grade to compensate for variations within this range (page 77).

From the practical point of view it is desirable to aim at a tone gradation in the negative which allows the choice of a medium contrast grade of paper for enlarging. Despite the variations of subject tone range mentioned above, the production of such negatives is mainly a question of correct development – i.e. the choice of a suitable developer and right development time. In a negative of suitable tone range the shadow details of the subject should be clearly distinguishable – a matter of adequate exposure, provided this is not spoilt by under-development. Likewise, the highlight areas in a negative should not become too dense. A simple way of visual assessment of the negative is to hold it against a printed sheet, like a page of this book, in good light. The printing should then just be readable through the densest part of the negative.

To produce negatives of good printable quality, the gamma (page 68) of the characteristic curve should be kept within a range of 0·7 to 0·9 by appropriate development. The gamma of miniature negatives can even be somewhat lower still – between 0·6 and 0·7. For a high gamma also leads to higher maximum densities. At the high degrees of magnification often called for with miniature negatives these densities may well require excessively long exposure times.

For special purposes, such as press or industrial photography, negatives of a gamma between 0·9 and 1·2 are often preferred. This is more suitable for larger negative

formats where the degree of final enlargement is lower. The exposures must however then be more accurate to avoid the production of very dense negatives which become inconvenient to print.

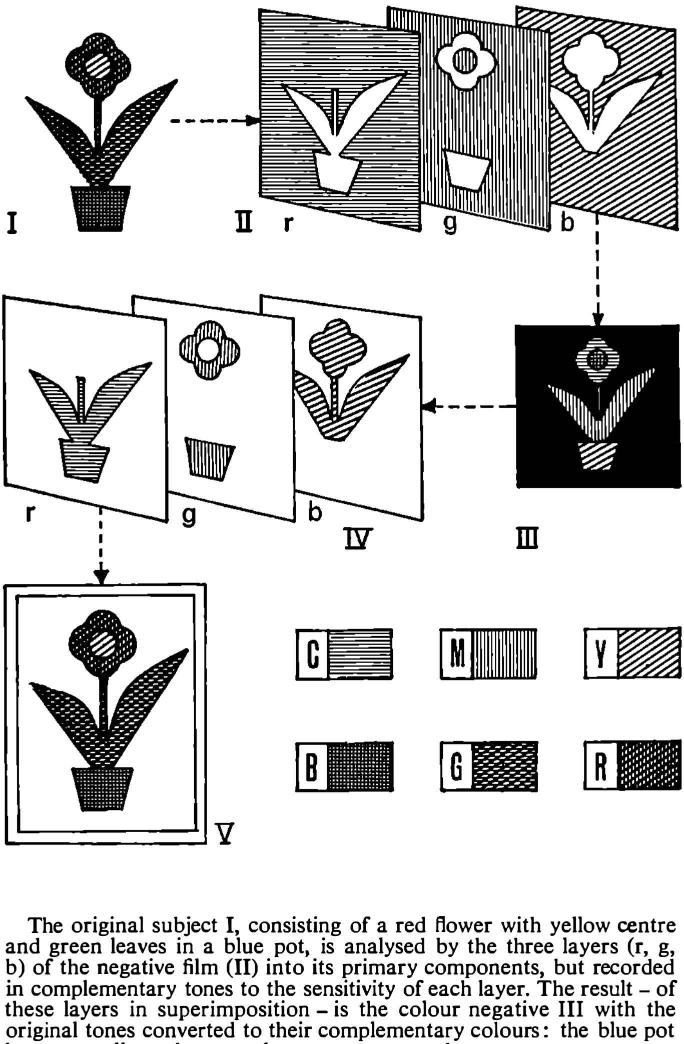
Some film manufacturers specify recommended development times with reference to a mean gradient or $\overline{G}$ value (also known as "beta" value), or to a contrast index, rather than gamma. This takes account of the fact that with many modern negative materials only a comparatively short section of the characteristics curve is really straight. There gamma becomes a misleading quantity on which to base a development contrast assessment. This does not however affect the principles of matching negative and paper contrast discussed in the next chapter (page 75).

COLOUR NEGATIVES

The negative image formed in colour films corresponds in many of its characteristics to a black-and-white negative. Thus it reproduces subject tones in a range of reversed image tones in the negative. The colour negative image has characteristics of granularity, sharpness and gradation, even if these properties differ in some respects from those of a black-and-white negative, as we shall see in a moment.

Most important however in a colour negative is the fact that the image also records colour values of the original scene, and not only brightness values. These colour values are reversed and the colours shown in the negative are more or less complementary to those of the original subject. Thus blue tones, such as the sky, in the scene photographed by the camera appear as yellow to brown tints in the colour negative; similarly, flesh tints are reproduced greenish, reds as blue-green, greens appear pink to purple and so on. During the colour printing process these colours are reversed once more to produce afresh the original tones of the subject, or at least a reasonable approximation of them. During colour enlarging we can indeed control the colour reproduction of the print by using colour filters (page 194).

The colour image in a colour negative is due to the fact that the latter carries three emulsion layers which respond in effect to blue, green and red light respectively. The colour film analyses subject colours in terms of their blue, green and red components. (Most systems of colour photography are



The original subject I, consisting of a red flower with yellow centre and green leaves in a blue pot, is analysed by the three layers (r, g, b) of the negative film (II) into its primary components, but recorded in complementary tones to the sensitivity of each layer. The result – of these layers in superimposition – is the colour negative III with the original tones converted to their complementary colours: the blue pot becomes yellow, the green leaves magenta and so on.

On printing (IV) the colours of the negative image again record in the red (r), green (g) and blue (b) sensitive layers of the printing paper as complementary colour images. The resulting print (V) then shows the original subject colours. See also page 70.

based on the assumption that all natural colours can be matched by suitable combinations of blue, green and red light only. While this is only approximately true, the approximation is good enough to produce acceptable colour pictures by present-day colour processes.)

In the colour negative film all blue elements of the image – including not only pure blue details but also the blue component of such tones as violet, blue-green etc. – record in the blue-sensitive layer of the film. On processing, this layer yields – by a special development procedure – a yellow dye image, yellow being complementary to blue. Similarly, green image elements record in the green-sensitive layer of the film and there produce a magenta (reddish-purple) dye image. Finally, red tones record in the red-sensitive layer only, to yield a cyan (blue-green) colour image.

All three images are negative with respect to the colour brightnesses that gave rise to them. For instance the brightest green will produce the deepest magenta densities, and the darkest green the thinnest magenta deposit. The combination of these complementary dyes produces the reversed colours of the colour negative.

In practice the reversed colour nature of a negative image in many modern colour negative films is not quite so obvious because it appears overlaid by an orange-yellow tint (actually partial red and/or yellow positive images). This helps to improve the colour accuracy of the positive during printing. The complementary coloured negative image is however there underneath.

Unlike black-and-white materials, colour negative films exist in a limited number of types; there is not the same range of slow to fast, fine grain to coarse grain etc. emulsions. The basic characteristics of negative colour images on different makes of colour film are thus fairly similar. And since processing has to be very accurately controlled for faithful colour reproduction, we have little or no scope for altering the characteristics of negative colour films. In particular the gradation is fixed; it corresponds approximately to that of a medium contrast black-and-white film.

GRAIN AND DEFINITION OF COLOUR FILMS

While the image of a colour negative film has a certain granularity, this is in practice far less disturbing than the

grain of a black-and-white film. There are two reasons for that.

First, the dye images (formed as a by-product of the development process to a silver image – which is removed afterwards) do not consist of as sharply defined grains as a silver image, but of comparatively more blurred spots of dye.

Secondly, each dye image has its own random granular distribution. The contrast of the individual dye grain is very much lower than of corresponding silver grains, and grains in the three emulsion layers do not necessarily coincide in position. The net result is that the granularity of the negative colour image is far less visible. Graininess is thus much less of a problem.

Image sharpness on the other hand is less favourable with negative colour films. As we have three layers, the diffusion of light in the layers, and hence irradiation (page 55), is increased and a colour film cannot give an image as of high acutance as a black-and-white material.

Some manufacturers of negative colour films have suggested that such a film is a useful universal material for obtaining both colour and black-and-white prints. The colour negative can certainly be enlarged on a black-and-white enlarging paper, especially if the latter is panchromatic (sensitive to all colours, unlike normal enlarging papers – page 75). However the reduced sharpness due to the presence of three emulsion layers does not make a colour material the best negative film when primarily black-and-white prints are required. The dual utilization of such negatives for black-and-white and colour prints is thus something of a compromise.

COLOUR TRANSPARENCIES

Most of the time colour transparencies on reversal colour film are the end product of the colour photographic process. We can however also make prints from transparencies by enlarging them on to reversal colour paper which is then processed in the same way as the original transparency to yield a positive print. The quality of the latter is usually inferior to a colour print made via a colour negative, largely because the transparency – designed for direct viewing on projection – has far too great a contrast range for making prints. (See also page 320.)

The characteristics of grain, acutance and gradation (not to mention colour rendering) vary rather more in colour transparencies than in colour negatives. Here the range of colour film materials is greater, extending from slower emulsions of high definition to very fast ones of not so good definition.

Printing Papers

The printing paper is the raw material for the production of the positive picture. Being a light-sensitive emulsion coated on a suitable support, it has many properties analogous to those of a negative material.

Chemical and sensitometric characteristics determine the way in which the print reproduces the tones of a negative and the way in which it is processed. Physical properties influence largely the appearance of the print as such.

PRINTING PAPER EMULSIONS

Most conventional printing papers have, like normal negative materials, a silver halide emulsion. The silver halide used – generally silver bromide, chloride or a mixture of the two – largely determines the sensitivity of the paper. Thus silver chloride papers tend to be slow and can be handled in weak white light; they are used mainly for contact printing. Silver bromide papers are considerably faster and are intended for enlarging. In between, frequently used for slower enlarging papers, are chloro-bromide emulsions. See also page 78.

While speed in negative emulsions is usually specified on a numerical scale, no speed rating system for papers exists. There are two reasons for this.

Firstly, exposures required in printing and enlarging depend also very greatly on the enlarger, lighting and other printing conditions. These are far less standardised and consistent than the subject brightnesses which the photographer has to deal with in exposing the negative. Outdoor subjects, especially average scenes normally tackled by the amateur, are sufficiently easily classified in, for instance, exposure tables.

No such classification is possible for enlarging or printing conditions. So exposures have to be determined either by trial and error or by measurement based on previous calibration of the enlarging equipment (see also page 263).

Hence the usefulness of paper speed measurements is much more limited.

Secondly, and as a consequence of this, the manufacturing tolerances of printing papers as far as speed is concerned are less strict than of negative materials.

So we are left with the rather vague classifications of contact speed (possibly subdivided into slow and rapid) and projection speed – with similar variations. Comparatively speaking the fastest projection papers are about 100 times as sensitive as slow silver chloride contact emulsions.

COLOUR SENSITIVITY

Printing papers are generally not colour sensitised. That is, the emulsion is sensitive to violet and blue light, but not to other colours from green to red. There is of course no need for colour sensitisation, when we are printing from black-and-white negatives. The insensitivity of the emulsion to light of longer wavelengths is a practical asset since it permits handling of the paper by yellow or orange dark-room illumination.

There are three main exceptions to this rule:

(1) Variable contrast papers usually have at least one orthochromatic emulsion (sensitive to green and yellow light) because the colour of the enlarging light is here used to control gradation (see page 105). Warm-tone enlarging papers may also have a slightly orthochromatic emulsion.

(2) Certain panchromatic enlarging papers are sensitive to all colours and are designed for making black-and-white enlargements from colour negatives. While ordinary enlarging papers can be used for that purpose, they are liable to distort the tone values of subject colours. In particular greens, blue-greens and blues are liable to be reproduced too light in a print on a normal bromide paper, because these tones are yellow to red in the colour negative. A panchromatic enlarging paper thus gives a more faithful reproduction of the brightness values of different colours. The orange-red masking image in many modern colour negative films distorts tone values still further and leads to very long printing times with an enlarging paper which is only blue sensitive.

(3) Colour papers for making colour prints of course also have to be sensitive to all colours (page 111).

GRADATION AND CONTRAST GRADES

Like negative materials, printing papers can have different gradations – i.e. different rates at which equal logarithmic steps yield increases in tone from white to black on development.

This becomes apparent from a strip exposure test as described on page 63. We thus have soft papers which show a long range of grey tones before the fullest black appears and thus require a long range of exposures to bring out both full white and full black in a print. On the other hand a high-contrast paper shows very few grey tones between full white and full black and can consequently accept only a short range of exposures before the full black is reached.

A given negative material is generally made in only one gradation, which is variable within certain limits by controlling the degree of development. Special types of film have to be used for subjects of particularly high or particularly low contrast. Printing papers on the other hand are generally made in a range of gradations for routine work with a paper of a particular type. These different paper grades are required to enable the photographer to make the best possible print from every type of negative, from soft to hard. In that way negatives of different gradation can reproduce the full tone scale in the print from white to full black.

Paper grades are classified according to an arbitrary and sometimes vague scale, either with descriptions ranging from extra soft through normal to vigorous or contrasty and ultra hard – or by numbers from 0 to 5 or more. There is no standard system for labelling or specifying paper grades, and for instance a No. 2 paper made by one manufacturer does not necessarily correspond to the gradation of the No. 2 paper of another make.

PROCESSING

Enlarging papers – and many contact papers – for making positive prints from black-and-white negatives are development materials. That is, the visible image only appears when the exposed paper passes through the development and other processing steps. This is in contrast to printing-out papers which yield a visible image during exposure and which were popular half a century or more ago. They disappeared from

general photography because their extremely low sensitivity called for long exposures (running into minutes) by daylight or intense ultra-violet sources which made them unsuitable both for enlarging and for economic commercial printing. Printing-out materials are presently limited to certain very special technical applications.

Processing of development papers can still take place in two fundamentally different ways. The first, classical, method is to immerse the paper in succession in the developing and fixing baths. This process takes a certain amount of time but also offers some processing control and permits observation of the image during development.

The second method is machine processing, utilising papers which incorporate the developing chemicals already in the emulsion. Here the paper is passed through a processing machine which brings it into contact first with an activator solution to start the developing process and then with a stabiliser solution. This has the same role as the fixing bath in conventional development papers. Here processing takes only a few seconds and far less trouble. These methods are discussed in detail in the chapters on paper processing.

Machine processing is now also applied to more traditional papers without chemicals in the emulsion and there takes a little longer (or takes place at a higher temperature) than with activator/stabilisation papers. Originally the latter evolved for wet office copying systems but are now marketed for professional and amateur enlarging and contact printing. Certain special processes even use enlarging (and contact) papers which require no wet processing at all; the image is produced merely by heating (page 453).

PAPER TYPES

Commercial descriptions of paper types tend to be vague, partly at least because there is no generally recognised criterion for describing the technical qualities of printing papers. For reasons already indicated (page 75) there is no standard scale of paper sensitivities, nor have manufacturers come to any agreement over the naming or even specifications of contrast grades.

While papers are sometimes spoken of as being chloride, chloro-bromide or bromide emulsions, these distinctions tell us little enough. The chemical constitution of an emulsion

is no general criterion of its photographic qualities or even of its suitable range of use.

For this reason, classifications of printing papers group them according to their use rather than detailed chemical or sensitometric characteristics. While this involves some over-lapping (some paper types are suitable for a number of purposes) and certain anomalies, such a classification is sufficiently useful to permit a sensible choice of a paper type required for specific applications. It also has in its favour that paper manufacturers have organised their output broadly along similar lines. The groups concerned are:

(a) contact papers;
(b) enlarging papers;
(c) document copying papers;
(d) photo-mechanical papers.

CONTACT PAPERS

Papers in this group have very low sensitivity, and can be handled in weak artificial light or under a bright yellow darkroom safelight. They were known at one time as gas-light papers – a name which survived far longer than gas lamps for domestic illumination. The emulsions consist of either pure silver chloride or chloride with a lesser proportion of silver bromide. There are two main sub-groups:

(a) *Papers giving black or blue-black tones*, normally coated on a white base and containing silver chloride. They are made in a wide variety of contrast grades – sometimes up to seven in number – and in several qualities for amateur and professional use, commercial quantity printing etc. They exist both as normal contact papers requiring orthodox processing and as machine processing papers with developer chemicals incorporated in the emulsion.

(b) *Papers giving warm black tones*, containing also some silver bromide and often coated on a tinted paper base. These are offered by a few manufacturers and exist only without processing chemicals in their emulsion. They are somewhat more sensitive than black-tone contact papers, and are made in a limited range of contrast grades.

ENLARGING PAPERS

Papers in this class are much more sensitive – in practice thirty to a hundred times (sometimes even more) than black-tone contact papers. The emulsion consists either of silver bromide only or of bromide and a proportion of silver chloride. The main groups are:

(c) *Papers giving black tones.* These are usually pure silver bromide emulsions and are made in four or five contrast grades. They exist both as conventional development papers (without incorporated developing agent) and as machine processing papers with the developing chemicals in the emulsion.

(d) *Papers giving warm black tones* and containing a proportion of silver chloride with a greater quantity of silver bromide. These are made only for orthodox processing and are available in two or three contrast grades. Their sensitivity is on the average lower than that of bromide papers of group (c).

(e) *Variable contrast papers* (see page 105).

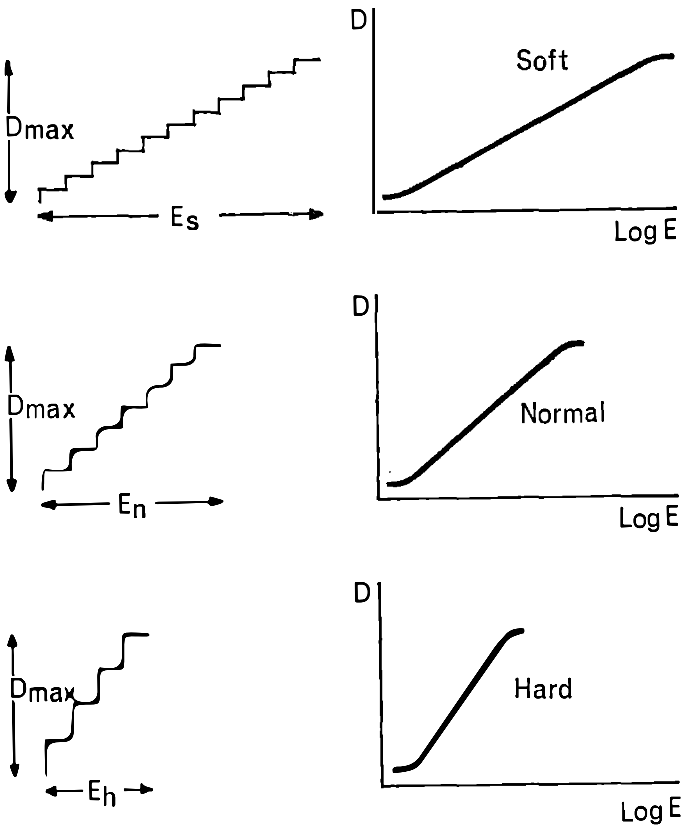
There are a number of further sub-divisions according to paper base for special purposes (for example waterproof) and sensitisation. Thus certain enlarging papers use an emulsion predominantly of silver chloride giving a warm black image, but dye sensitised to increase the speed. Since such papers are more or less orthochromatic instead of merely blue-sensitive, some care is required with respect to the safelight used. Fully sensitised panchromatic bromide papers are used for black-and-white prints from colour negatives (page 75).

DOCUMENT PAPERS

This class of papers became important in the 1960s in the rapid copying of documents and similar originals. Many of these papers incorporate developing chemicals in the emulsion, and they are usually available in one or two hard to extra hard contrast grades.

There are again contact and projection printing types differing mainly in their sensitivity. Contact document

PAPER GRADES



Enlarging papers usually have similar maximum densities to reach a full black in a picture. The different paper grades have however different exposure ranges. Thus the soft paper with its long range E_s can accommodate many negative tones between its white and its own full black, that is why it can cope with considerable negative density ranges and compress negatives of high contrast within the paper tone scale. The normal and hard paper grades have progressively shorter exposure scales E_n and E_h, though with the same maximum density, giving staircases or characteristic curves of increasing steepness.

papers were used in office copiers – now superseded by systems using dry chemistry – and for contact printing by transmitted light or reflex methods. Projection speed document papers serve primarily for re-enlarging from microfilm negatives or for optical copying in a copying or process camera. Materials for this latter purpose often approach negative emulsions in speed and may be orthochromatic or even panchromatic for copying from coloured originals.

Where contact copying papers are used for negative-positive copying systems the same emulsion serves for making the negative and the positive copies. Where negatives are produced in a camera on high-speed document paper, slower contact papers are used for making the positives.

In addition to silver halide papers employed for negative-positive copying, there are also various special copying materials, yielding for instance positive prints in one stage from a positive original. These are discussed further on page 488.

PHOTO-MECHANICAL PAPERS

Papers, usually of high-contrast characteristics, are also used in the graphic arts field for intermediate negative or positive stages involved in producing a printing plate from a photograph. Some of them are fairly similar to high contrast document copying and enlarging papers; others have emulsions designed for processing in special ultra-contrast developers. The image produced has also certain unusual characteristics, such as extreme edge sharpness. This is brought about by a deliberate inducement of edge effects similar in principle to those obtained by high-definition development on high-acutance films (page 62).

Apart from their applications in graphic arts processes, such papers (and corresponding transparency materials) are of interest for achieving pictorial high-contrast images, reducing a continuous tone picture to graphic abstract designs (see page 493).

TRANSPARENCY MATERIALS

While photographic enlargement generally implies a paper print, it need not do so. Disregarding transparencies for projection purposes (lantern slides etc.), prints on a film base are often used for display purposes in front of an illuminated surface, such as a light box.

Such a viewing arrangement is more complex than hanging an enlargement up on a wall and looking at it. But an illuminated transparency enlargement has the advantage of being able to display an immensely greater brightness range than a print viewed by reflected light (page 86). Such a picture, like a transparency projected on a screen, thus has far more brilliance and realism.

Transparency materials for enlarging are very similar to low-speed negative films; in fact many of the latter can be used for this purpose. There are also contact positive films – with or without incorporated developing agents in the emulsion – intended for producing intermediate positives in photo-mechanical reproduction and for mass copying processes such as dyeline. They can be used equally in intermediate stages of the production of high-contrast graphic effects.

Transparency materials are generally not available in different contrast grades. Emulsions for printing from continuous tone negatives are usually of fairly hard gradation, with the contrast controllable within limits by development. Copying and photo-mechanical films are nearly always ultra-hard.

THE RANGE OF BRIGHTNESSES

Before proceeding to the more practical aspects of the choice of a printing paper and especially of its contrast grade, it is useful to examine the basic difference between a negative image and a positive print. The former is seen or printed in transmitted light, while the latter is viewed by reflected light.

The maximum density which a negative material can reach varies appreciably with different films and their treatment in processing. The maximum black which a paper print can achieve is not only more limited, but also varies less among different papers. This is because as more silver is deposited in a print tone (by increased exposure), there comes a point when additional silver does not make this tone any blacker. This point is reached when the light reflected by the print surface in the blackest tone is greater than the light reflected by the paper base after passing through the silver deposit. (In fact the light passes through the silver deposit twice – before reaching the paper base, and after

being reflected from it.) So however much the maximum silver deposit increases, the maximum reflection density of this deposit is limited.

In practice the blackest black tone on a glossy print reflects at least a little over 1 per cent of the light falling on it. Usually this figure is nearer 2 per cent, rising up to 5 per cent with a matt print surface. As the whitest white of a print still absorbs around 20 per cent of the light falling on it, the total range of brightnesses between full white and maximum black is rarely greater than 40:1 (and often no more than half this figure). For this reason a very limited range of subject tones only can be reproduced in a natural contrast on paper.

TONE REPRODUCTION

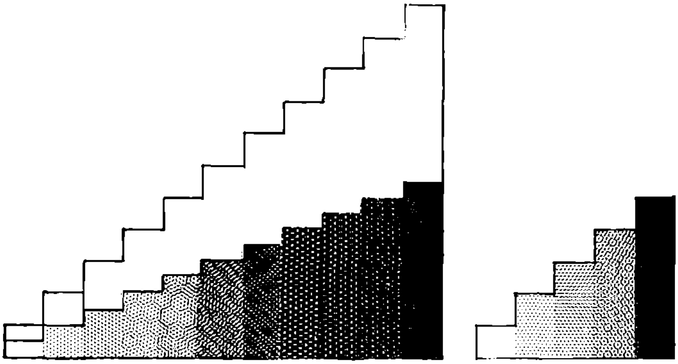
This restriction on tone range is inherent in the reproduction using a paper print. Our object in photography is to obtain as accurate a tone reproduction as possible of the various brightnesses of the original subject. In a negative-positive process this accuracy depends on:

(1) The camera lens;
(2) The negative material and its processing;
(3) The positive material and its handling.

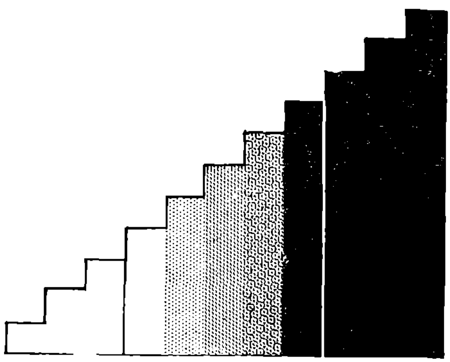
Considering first how the various tones of the subject are recorded in a negative, we have to define the brightness range of outdoor scenes. Obviously they vary very greatly, and we shall restrict our consideration to subjects with an average brightness range.

In their classical investigations based on a large number of exterior scenes, Jones and Condit (1940) came to the conclusion that the brightness range of the average outdoor scene is about 160:1. This means that the light reflected by the lightest subject tone, for example a cloud, is 160 times as intense as the light from the darkest shadow detail of any significance. Reproducing this full range on a film would involve an arithmetic exposure range of 160:1, or a logarithmic exposure range of 2·2.

The image produced by the lens in the camera should have the same brightness range as the original subject. In fact, flare (light scattering) in the lens reduces the image contrast and in practice helps to accommodate the brightness range



The density range of a transparency, or indeed of the transparent negative (represented here by the tall set of steps) is larger than that of a paper print (the lower staircase within the tall one). So when the negative is printed on a paper, the tone gradation is greatly compressed and the paper print looks much flatter than would for instance a transparency. The only way in which the contrast of a print can look natural is if the tone range of the subject is sufficiently short (*right*).



If we print a negative with its great density range on an enlarging paper so that the tone differences approximate to what they look like in the original, we must sacrifice tone reproduction at the upper or lower ends of the scale, or both. There will be darker tones which all merge into black, and lighter ones which all remain white.

of the scene within the exposure range of the negative material. (This flare factor is less important in current coated lenses than it was in the uncoated lenses available in 1940: on the other hand even coating does not completely eliminate it.)

If we disregard lens flare, the logarithmic brightness range of 2·2 of the average subject would require a negative emulsion with a logarithmic exposure range of at least 2·2. Developed to gamma 1·0, the whole brightness range of the scene would then be contained in a density range of 2·2 on a negative. In fact most modern emulsions have a much larger exposure range than normally required. So there is no difficulty in reproducing the tones of such a scene with a satisfactory degree of accuracy in the negative – even allowing for tone distortions of the toe and shoulder of the film's characteristic curve.

However the negative is only an intermediate stage: we are after a positive print showing all the negative tones. This is where the restricted density range of a print becomes awkward. A tone range of 40:1, referred to above, corresponds to a (logarithmic) density range of 1·6. Even with a highly glazed glossy print the density range never exceeds 1·9, and this poses a fundamental difficulty in printing.

Some compression of the brightness range of the subject is inevitable when the latter is reproduced in the print. The compression is naturally greatest if the original brightness range was high. For this reason professional photographers aim to control the brightness range of their subject – where possible, such as in the studio – by appropriate lighting (for example fill-in lighting for dark shadows).

Since a photographic print is an abstraction of reality anyway, we tend to accept a certain tone compression without losing too much of the realism that the print image can convey. When the tone compression becomes considerable, the print ceases to be acceptable. This is not because of the compression of the overall range, but because of the flattening of the intermediate steps. When we look at a scene, we never see more than a small part of it at a time. The eye constantly adapts itself to the average brightness of the part it actually scans over. This is why we can become aware of detail in very deep shadows as well as in very bright highlights

of an outdoor view: we do not normally register both simultaneously, but in succession.

So we tend to be accustomed to seeing a fairly high visual contrast of detail. In a print with a compressed tone gradation this detail contrast is equally reduced. Hence the picture looks flat and lifeless, even though it contains all tones from pure white to full black. A subject of shorter brightness range, accommodated within the same tone range of a print, is acceptable because the detail contrast of the picture corresponds more nearly to the detail contrast we saw in the original object.

To print a negative of long tone range acceptably we have to sacrifice part of the detail at one or other end of the tone range. Thus we may decide that dark shadow detail in an against-the-light shot is unimportant, and place only the lightest to middle tones in the brightness range of the paper. Anything darker in the original subject will reproduce as a detailless silhouette. Alternatively, we can fall back on certain more complex printing procedures to compress the overall tone scale while preserving detail contrast (page 48).

CHOOSING THE PAPER CONTRAST GRADE

When printing a negative of a subject of average brightness range, we must at least ensure that we obtain on the print the full range of tones from white to maximum black. This reduces any tone compression to a minimum. The first step here is to choose the right paper grade for the negative.

Stated in popular terms, the paper grade should compensate for the negative contrast: thus a soft paper would be required for a negative of high contrast, and vice versa. This general principle is set out in Table VI.

VI – NEGATIVE CONTRAST AND PAPER CONTRAST

For a Negative which is	*Choose a Paper which is*
Flat	Extra-hard
Soft	Hard
Normal	Normal
Hard	Soft
Very hard	Extra-soft

The choice of the paper grade is in fact determined by the density range of the negative. For instance a negative with a short density range requires a paper with a short exposure scale. This is a paper which has a curve with a steep gradient since the tones reach maximum density within a short range of exposure steps. Since different paper grades have practically the same maximum density, a longer exposure scale corresponds to a curve of flatter slope – i.e. a softer grade. This would be required for a negative with a long density range.

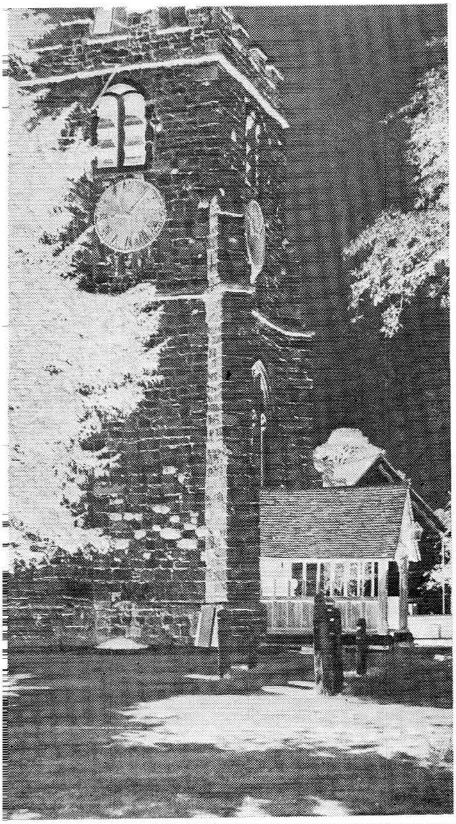
To obtain good prints, the density scale of the negative should match the exposure scale of the paper. If the exposure scale of the paper is too long, the density range of the negative does not cover all the tones from white to black in the paper, but possibly only from light grey to just past mid-grey. This leads to a soft print, i.e. the paper is too soft for the negative in question. On the other hand, if the exposure scale of the paper is too short, density differences either in the shadows or in the highlights cannot be reproduced.

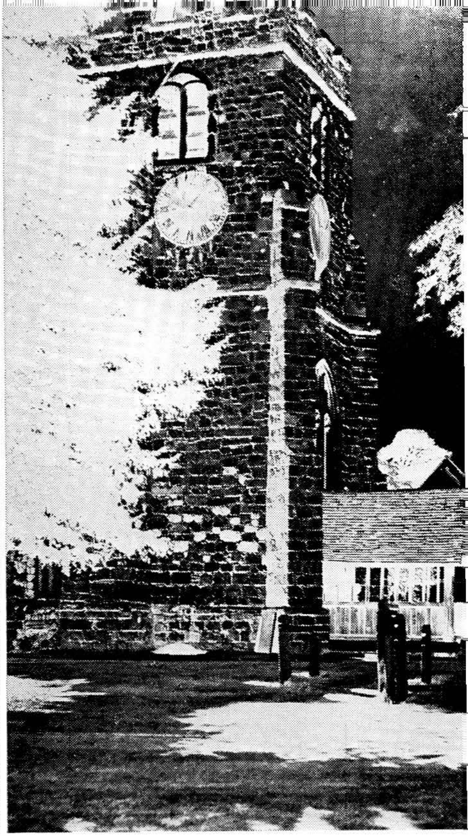
VII – APPROXIMATE EXPOSURE SCALES OF PAPER GRADES

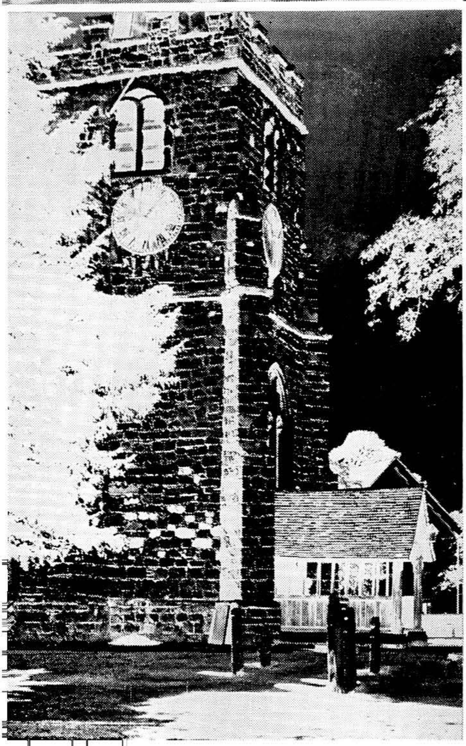
Grade	*No.*	*Exposure Scale (Approx.)* *Arithmetic*	*Logarithmic*
Extra-soft	0	45:1 and over	1·65 and over
Soft	1	25:1 to 40:1	1·40—1·60
Normal	2	13:1 to 25:1	1·11—1·40
Hard	3	9:1 to 13:1	0·95—1·11
Extra-hard	4	5:1 to 8:1	0·75—0·90
Ultra-hard	5	3:1 to 5:1	0·50—0·70

Note that the density range of the negative is not necessarily the same as the contrast – the latter is also determined by its gamma. However, when we judge negatives as soft, normal or hard, we generally assess the visual impression of density range, since we cannot estimate gamma by just looking at a negative. (See also page 89.)

A negative of normal density range but low gamma has a long exposure scale. This, when printed on a normal paper, results in the compression of tones we have already noted – even though the print may show all tone values from white to black. For this reason we must qualify







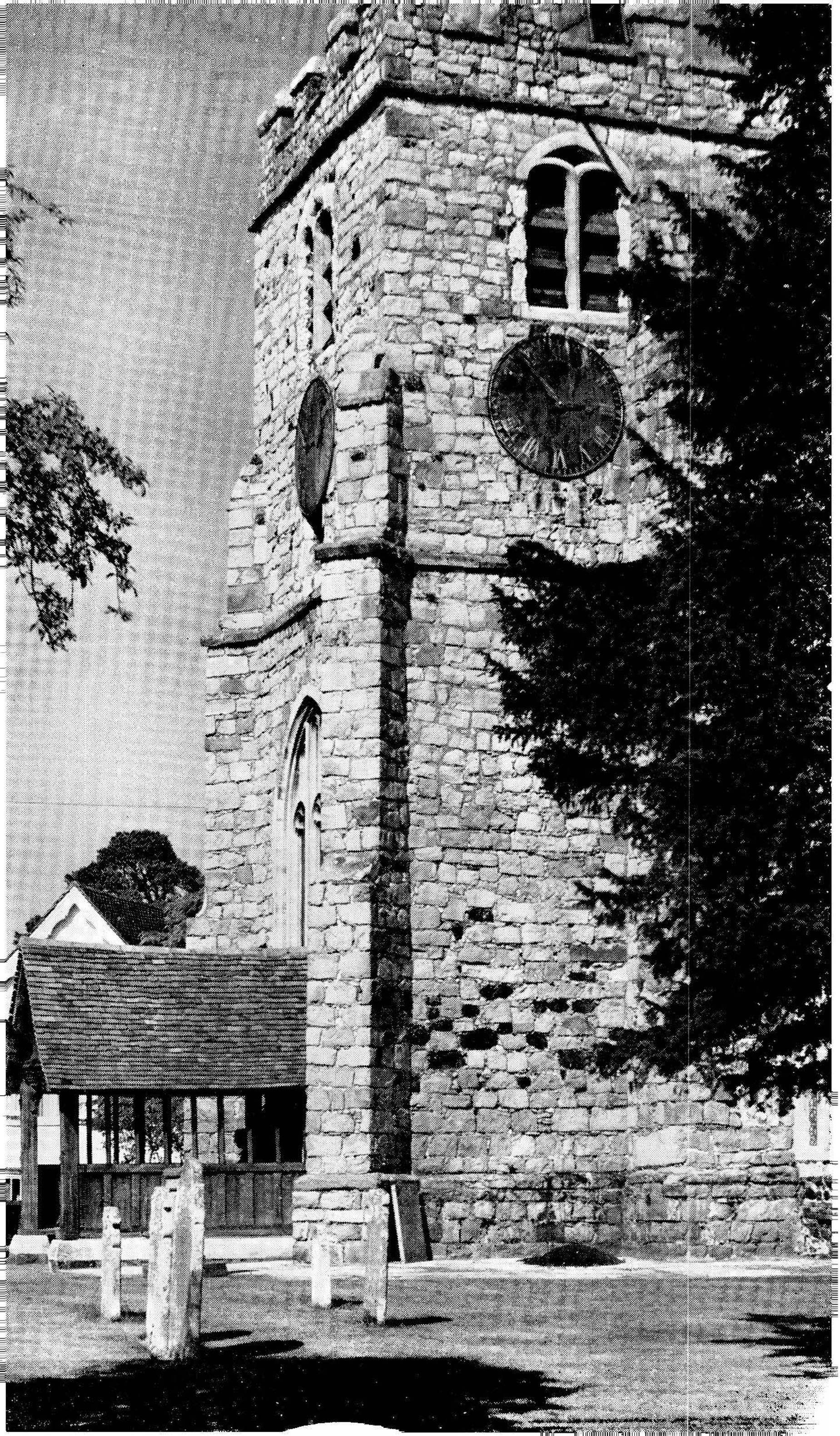
ESTIMATING NEGATIVE CONTRAST. Strictly speaking we have to estimate the negative density range, for this determines the paper grade required in printing.

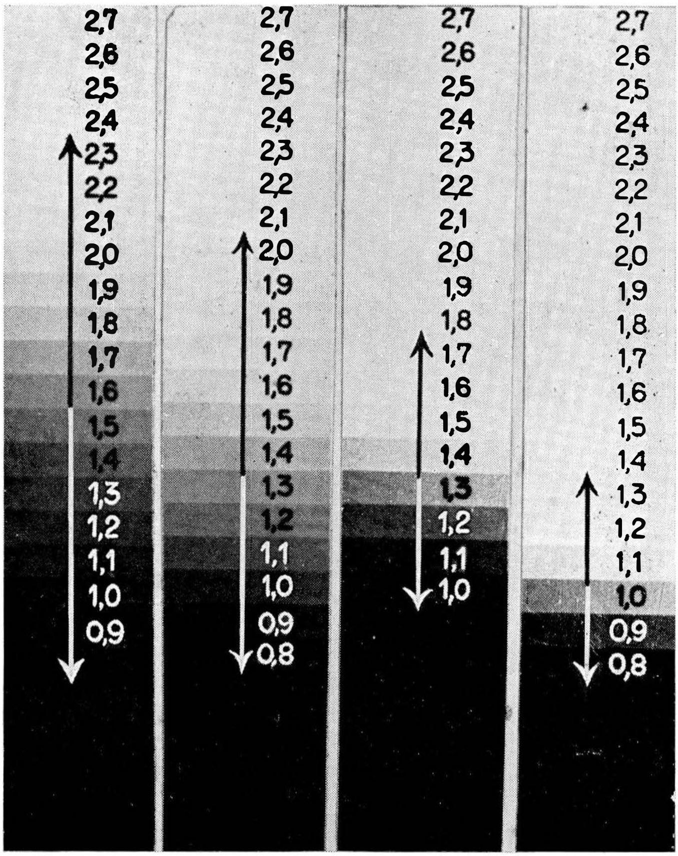
Above left: This is a soft negative with good shadow detail but not very dense highlights. It needs a contrasty paper.

Above right: A normal negative has a good range of tones from near transparent to fairly black. It should print well on a normal paper.

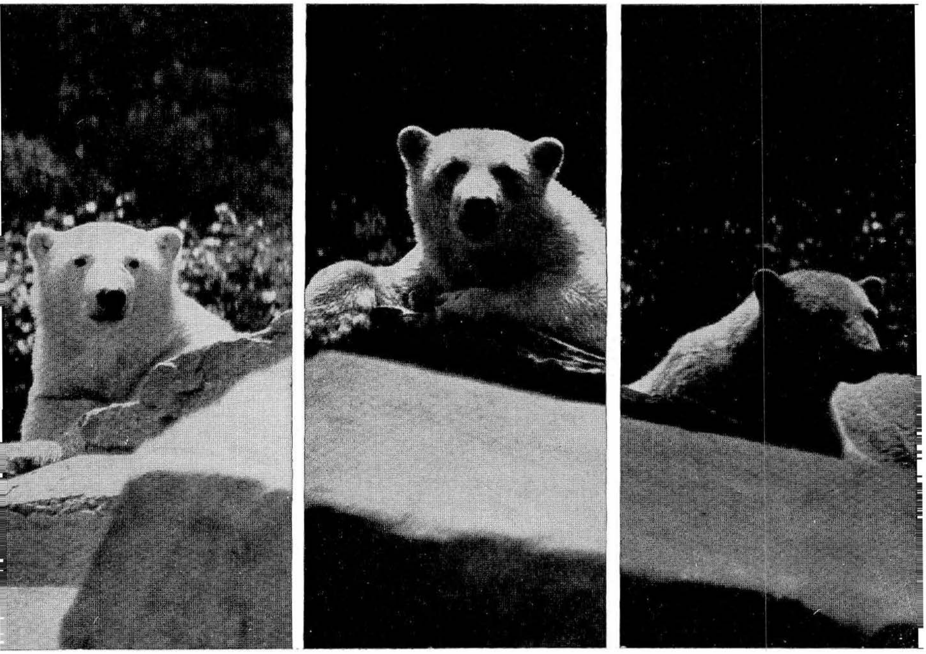
Left: A contrasty negative still has fairly thin shadows but very dense black highlights and needs a softer paper.

Page 90: The perfect positive print shows full tones from virtually black shadows to near white highlights. Photos: *Cyril Peckham.*





PAPER GRADES AND EXPOSURE SCALES. The difference between the various grades of printing paper is the exposure range; this determines the density range in a negative which the paper can match with a tone scale from white to black. The four tone scales here show—*from left to right*—soft, normal, extra hard and ultra hard grades of paper. The soft paper here has an exposure scale of 1.6 (40:1) and can produce a large number of tone differences within that scale. At the other end of the range, the ultra hard paper with an exposure scale of 0.6 (4:1) covers only a small number of steps between full white and full black.



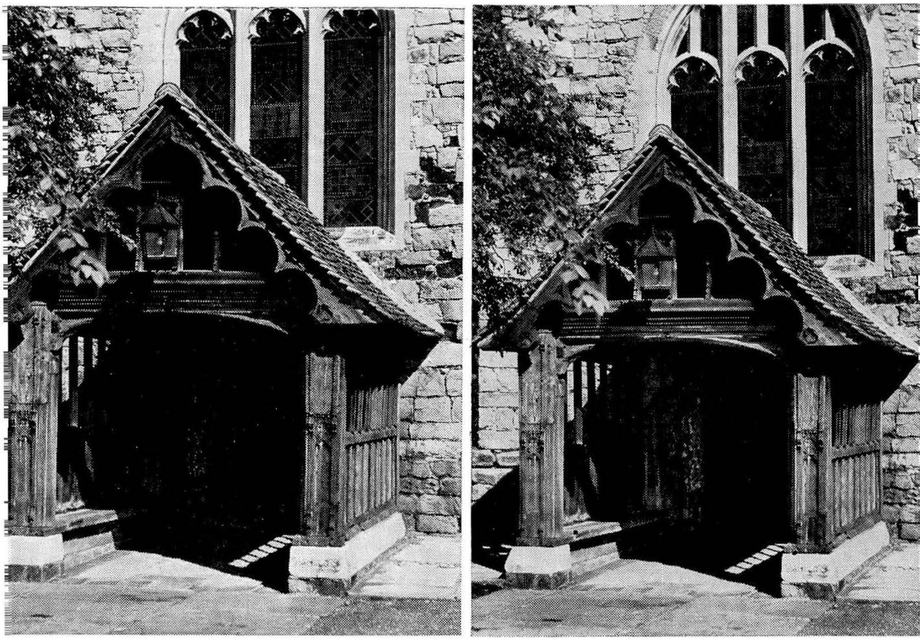
On pages 92 to 93: THE INFLUENCE OF PAPER GRADATION. The comparative examples show how different papers with a given negative lead to a different print contrast. Photos: *Cyril Peckham.*

Page 92, top: With a normal negative a soft paper yields a distinctly hard print with grey shadows and muddy highlights.

Page 92, bottom: A print on normal grade paper reproduces the full tone range from white to black.

Page 93, top: A hard paper shortens the tone scale; both highlights and shadows lose detail.

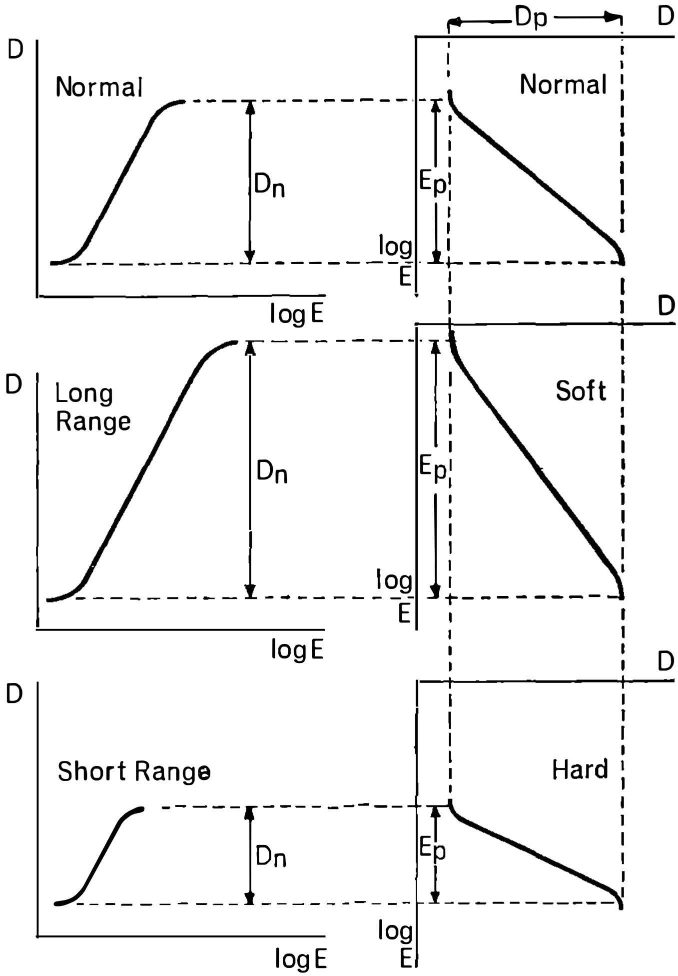
Page 93, bottom: With an extra hard paper virtually all gradation disappears except in the middle tones. Everything darker merges into black and everything lighter into detailless white.



Above: SHADING. Sometimes different parts of a picture need different exposures, which can be taken care of only by holding back part of the image in enlarging. This is the process of shading (page 412). Here shading has reduced the exposure in the dark doorway (*left*) thus preserving more detail (*right*). Photos: *Cyril Peckham*.

Opposite: CORRECT EXPOSURE. The simplest way of establishing the print exposure time is with a test strip. In the example opposite, the *left-hand* portion is under-exposed, for the shadows have nothing like a full black and the highlight details are missing. In the over-exposed portion (*right*) the shadows are too dense and the highlights veiled over.

PRINT SHARPNESS is subject to various enlarging hazards, even if the negative is sharp. The most obvious cause is faulty focusing; less obvious is enlarger vibration (*right-hand half of picture*) caused by unsteady setting up, touching the enlarger during or immediately before the exposure, or just walking about in the darkroom while the exposure is taking place.



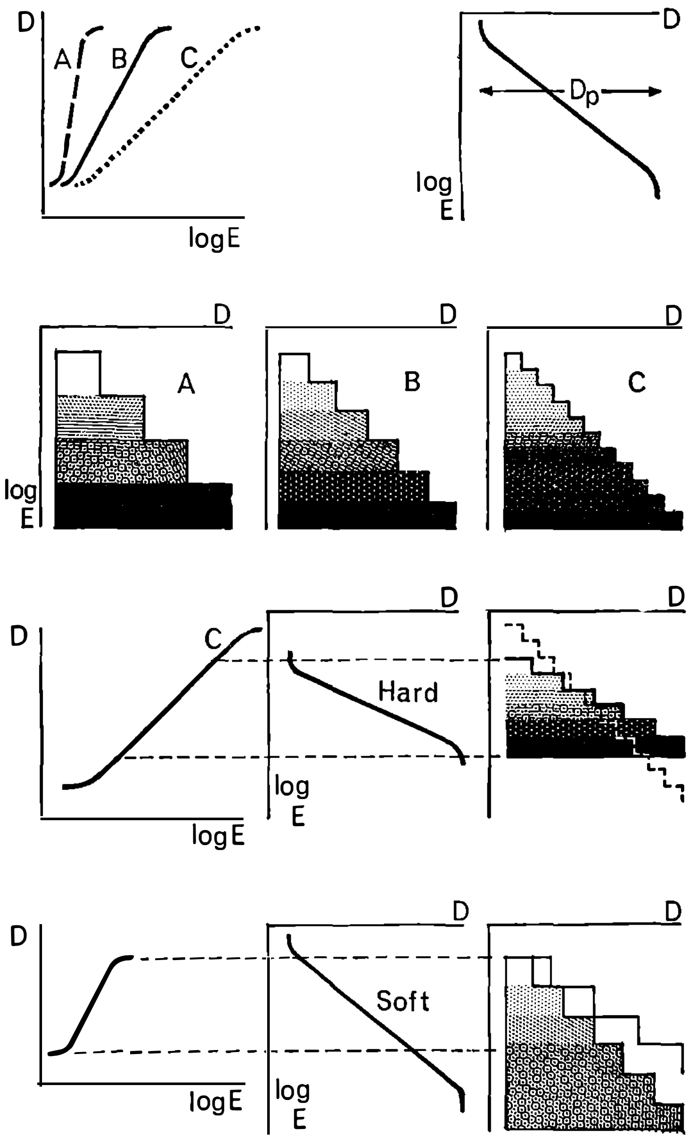
The curves at the left are characteristic curves of a normal, a long range and a short range negative, D_n representing the negative density range. The curves at the right are characteristic curves of normal, soft and hard papers, turned round here through 90°. The paper density range D_p is always the same; for the correct choice of paper grade we must match the exposure range of a paper E_p to the density range D_n of the negative.

When the negative density range (*left*) is matched to the paper exposure range, the resulting print gradation still depends on the negative contrast. Here A is a contrasty negative, B a normal negative and C a soft negative. (The slopes of all three curves as shown here are exaggerated for clarity).

In the resulting prints A will yield an image with few but well separated steps, B a normal one and C an image with many fine tone differences. So although the three have the same density range on the paper, A will look too contrasty and C too soft.

To reproduce negative C more naturally it may be necessary to use a harder paper and sacrifice part of the negative density range. That way a shorter range of negative tones is expanded into the density range of the paper, so that the result looks more natural, though extreme highlights and/or shadows may be lost.

With a very short range negative (like that corresponding to the bottom left-hand curve on page 97) it may be better to desist from matching it to the full paper range. If we in this case use a softer paper, the print will show for instance only light to medium tones, but the result does not have the inflated contrast obtained with a harder paper. This state of affairs corresponds to a high key picture.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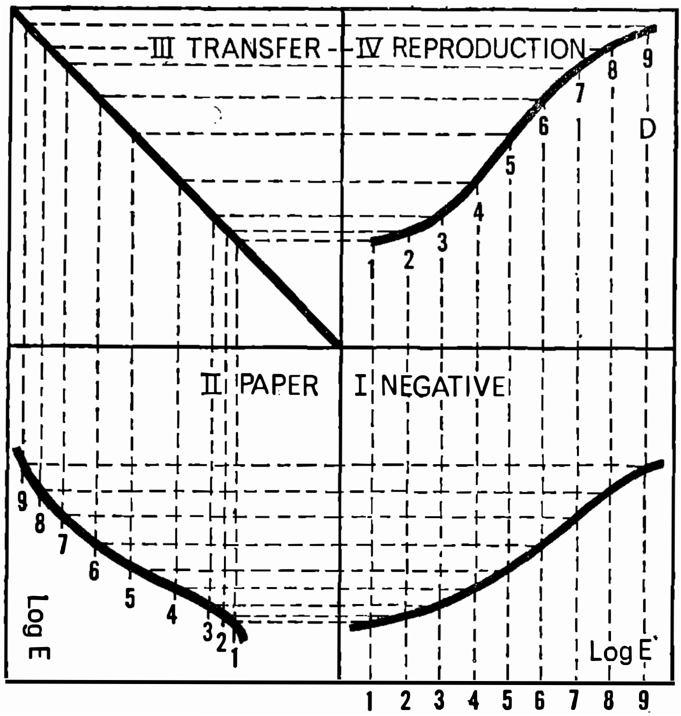
somewhat what we have stated on page 69 when discussing negative gradation. A soft gradation material (or a negative developed to a low gamma) is only a partial answer to a subject of extreme contrast. A reduced negative contrast will certainly compress the tone range into the exposure range of the paper, but it will not ensure a faithful reproduction of the subject in the print. The result is an inevitable compromise between acceptable and necessary tone compression.

In the last resort the only way of ensuring a print or enlargement of good tone gradation is to start with the subject and bring down its brightness range within the tone range which a print can show (page 86). If the subject has too great a brightness range, we have to ignore part of it – for example by allowing tiny and insignificant shadows to print detailless black when we are dealing with an outdoor scene in bright sunlight. If however there are large deep shadows as well as brilliant highlights and the shadows should still show detail, some form of fill-in lighting is essential.

This is the justification of the present popularity of fill-in flash even in outdoor sunlit scenes, however much this device is sometimes abused. Equally, it is the reason why professional photographers make a special point of illuminating the shadows in portraits and other indoor set-ups.

Conversely, a short-scale negative can still be contrasty – i.e. have a curve of steep slope. This is less frequently met with in practice, because high-contrast negative materials also yield high maximum densities. It would require extremely precise lighting and processing control to restrict this density range to a low value without flattening the contrast. In the rare cases where this does occur, a print on a hard paper grade would make such a picture look too contrasty, even though no highlight or shadow detail is lost. The harshness of the effect can only be modified by printing such a negative on a normal or even soft paper grade, and recording only the highlights and medium tones, without going to a full black.

This is what happens with a high-key print. This is obviously not the same thing as a soft print, for the detail contrast is normal – only the tone range is restricted. We shall come back to that on page 406.



Quadrant diagrams are used to assess the effects of different reproduction stages on the gradation of the final result. Thus if we start with a series of evenly spaced subject tones, numbered here from 1 to 9, the first quadrant shows how these tones are recorded in the negative. The second quadrant plots these negative tones on the paper curve, from which a reproduction curve (IV) is obtained. As is seen here, the tones from 1 to 9 are by now bunched both at the lower and at the higher end of the density (D) axis, and spread out in the middle. The transfer quadrant (III) is used merely to transpose the reproduction curve into the same conventional form as the original negative curve. It is this reproduction curve which specifies the characteristics of the system as a whole.

Even if we have correctly matched the density range of the negative and the exposure range of the paper, some tone distortion in different parts of the tone range will arise. This is due to the shape of the characteristic curves of both the negative and of the paper. One way of investigating how close we can get to good tone reproduction is the quadrant diagram (page 101), following the method of L. A. Jones.

In its simplest form, this diagram consists of four quadrants showing in the first and second the characteristic curves respectively of the negative material and of the paper. A series of points, corresponding to selected exposure levels on the negative, are traced on to the paper curve. The corresponding points from there are traced to the next quadrant. This is a transfer quadrant which serves simply for reversing the orientation of the paper curve to the final reproduction curve. The latter is obtained by geometric plotting of the selected points via the other quadrants.

For accurate reproduction the final curve should be a straight line at 45° to the axis. This will indicate that the densities of the print are proportional to the brightness values of the subject.

In fact however the curve is more or less S shaped, due to the fact that the characteristic curve of the negative and positive material are not uniform in slope. The reproduction curve is rather steeper in the middle, indicating higher contrast, while both ends are flattened – rather like the characteristic curve of the negative material, but deviating more strongly from straight-line reproduction. This means that highlights and shadows in the print are compressed. The characteristics of the printing paper further impair the already faulty tone reproduction of the negative material. Such distortion is least if the negative densities corresponding to the subject tones all lie on the straight-line portion of the negative curve. Ideal tone reproduction is virtually impossible to achieve, but good positive technique can obtain very satisfactory results.

The value of the quadrant diagram is that the effect of lens flare in the camera, viewing conditions, special treatment of the negative etc. can be represented in the same way

by introducing additional transfer quadrants. Further, the effects of tone correction, introduced into a quadrant diagram in a similar manner, are immediately visible in the reproduction curve.

SHORTCOMINGS OF PRINTING PAPERS

The restricted tone scale which a paper can reproduce compared with negative material is one inherent disadvantage of photographic papers. A second one is the lack of exposure latitude.

Actually a little consideration will show that this lack of latitude is in part at least also inherent in positive reproduction. For the exposure latitude of the negative simply implies that the brightness range of the subject can be matched – if short enough – to different parts of the exposure scale of the negative material. If these different sections all correspond to the straight line portion of the negative characteristic curve, we have a series of "correct" exposures which yield negatives of different density, but correct tone reproduction. (Owing to increased grain and loss of acutance, negatives which have received more than the minimum correct exposure are likely to be slightly inferior in quality – page 54.)

It is precisely this permissible variation in density which is absent in a positive print. Different densities in a negative can be compensated by adjusting the printing exposure; on the print however both the minimum density and the maximum are fixed. Increasing the exposure leads to too dark a print with all shadow detail submerged in blackness; too little exposure gives too light a print with no highlight detail. Exposure variations can reproduce the full density range of a negative in the print only if the exposure scale of the latter is longer than the negative density range – i.e. the printing paper too soft.

The desire to improve the properties of papers, particularly in the direction of better latitude, is emphasised by the recommendations of a scientific and technical committee in the United States for inventions and improvements in various industries. In the inventions most desired in photography there figured prominently "an enlarging paper coated with an emulsion having the same latitude as the modern film".

How far can this desire be fulfilled? There are two possible directions of progress: modifications in the character of the emulsion, and variations of developer and development.

Let us consider the second possibility first. In developing a negative we can appreciably alter its gradation by varying the development time. Positive emulsions do not react in the same way to development time. So the effect of varying the duration of development is much less than in the case of negative emulsions. There is the added disadvantage that too short a development time may lead to undesirable image colour, while with too long a time there is a real danger of fog or staining. This applies even to two-bath development methods with their wide scope of controlling negative gradation.

Developer additives such as present-day restrainers represent some progress in this direction. With such a substance added to the developer it is at least possible to increase the development time to obtain greater density in an under-exposed print, or shorten the development time to compensate for over-exposure, without appreciable loss in image quality or even gradation.

By a choice of suitable developers it is equally possible to modify the contrast grade of the paper. Thus a high contrast developer based on hydroquinone makes the paper grade effectively harder, while a soft developer based on metol can increase the exposure scale of the paper. In practice however the control possibility offered by working with different developers (or their mixtures) is rarely worth while. On the one hand the total control range available by such means does not amount to much more than the equivalent of one paper grade interval. On the other, it is far less trouble to have several paper grades at hand than several developers.

Modifications in the emulsion are much more promising. By using two emulsions of widely different characteristics it is possible to obtain a range of exposure scales in one and the same paper. Such emulsions could either be mixed together or coated on top of each other. For a hard negative we can then use the paper in such a way as to obtain a soft result by using the "soft" part of the mixed emulsion. Similarly for a soft negative we can so arrange matters that only the "hard" part of the emulsion is employed. For a

normal negative the effect of both emulsions together would yield a normal gradation in the enlargement.

VARIABLE CONTRAST PAPERS

The practical way in which such selective use of different emulsion components on one paper can be realised is by different colour sensitivities. Based on ideas by R. Fischer and patented as long ago as 1912, variable contrast papers were first developed by the work of F. F. Renwick in 1940.

Such a variable contrast paper is coated with mixed emulsions. One of the emulsions is non-colour sensitive, while the other is sensitised to the green region of the spectrum. This green-sensitive emulsion is of high contrast, equal to an extra hard grade of bromide paper. The non-colour sensitive emulsion is of soft gradation, about equal to a good soft bromide paper. The mixture is balanced in such a way that the ordinary printing light forms the image mainly in the non-colour sensitive (soft) layer.

For more contrasty prints the light is then modified by a yellow filter placed in front of the enlarging lens. There are two ways of exposing:

(a) by selecting one of a range of yellow filters of different strengths;

(b) by exposing the print without a filter for part of the time and through the deep yellow for the rest of the exposure.

The deeper the yellow filter chosen for the whole exposure, or the longer the proportion of the split exposure through the yellow filter, the higher the contrast of the print. By the split exposure technique in particular, the contrast can be very closely controlled.

Instead of a mixed emulsion, a variable contrast paper can have two emulsions on top of each other: a contrasty orthochromatic one and a soft blue sensitive one. Equally, the sensitivities can be reversed so that the blue-sensitive emulsion is the hard one and the green-sensitive emulsion the soft one. In this case contrast control would be obtained by using a range of blue filters of increasing density for harder prints.

If the two emulsions are so balanced that white (unfiltered) light gives a print of normal gradation, a range of

both blue and yellow filters of different densities would shift the contrast in either direction.

Split exposure techniques are then possible using only the deep yellow and the deep blue filter. The practical advantage of this, provided that the filters are adjusted to have equal filter factors, would be that no exposure adjustment is necessary for prints of different contrast.

One make of variable contrast paper uses only one emulsion, basically a high-contrast one dye-sensitised by a special method. Experiments with suitable sensitising dyes showed that a variable contrast effect could be obtained when considerably less dyestuff was used than necessary to give the maximum sensitivity obtainable by that dye.

MODIFYING PRINT GRADATION BY CONTROLLED FLASHING

It is also possible to control the print gradation by supplementary flashing of the paper. The effect on photographic emulsions of such a supplementary exposure before, during or after the actual printing, has long been known in principle, but has found practical application only comparatively recently. It is usable with practically any type and make of enlarging paper. The method is widely employed in photo-finishing in connection with rollhead printers where it is more convenient to work with one paper grade only and not waste time to change over between different papers.

The principle is that an additional exposure can be given which is just below the fog level of the paper, but will reduce its contrast. The basic paper is therefore a hard or extra hard grade, and all contrast grades can be obtained down to very soft by varying the flashing exposure.

The practical application of the method is quite simple. The enlargement is made in the usual way. The only difference is that during part of the exposure time light is permitted to reach the paper which is either not passed through the negative at all, or has been so diffused (for example with a ground glass in front of the lens) than it does not produce a sharp image.

The basic time for the additional exposure is determined by fogging a strip of the paper step-wise. The exposure which is just below the fog level is the longest exposure which can be given to the paper in question to get the lowest

possible contrast, Intermediate grades are then obtained by reducing the exposure accordingly. If no ground glass screen is used, the negative must of course be removed from the enlarger. The flash exposure is then 10 to 20 per cent of the main one.

Using a ground glass diffuser, the auxiliary exposure is about as long as the original exposure for the enlargement. Once this ratio has been determined, it remains the same even if the negative (and the exposure itself) is changed.

THE COMPONENT LAYERS OF PRINTING PAPERS

How is a printing paper made up? A very thin cross-section examined edgewise under a microscope would show the construction of the different component layers as follows.

In the first place, the paper base itself consists of a particularly pure and high-class raw paper. On top of the base is often a thin layer of baryta – a suspension of tiny grains of barium sulphate in gelatine. The function of this layer is partly to keep any impurities in the paper from the sensitive emulsion (but with the quality of present day raw papers used for this purpose such a layer is nowadays largely superfluous in this respect). However the baryta layer also gives extra purity to the whites and stops the emulsion from being absorbed by the paper base, which would tend to lessen the brilliance of the image later on.

On top of the baryta layer is the actual sensitive emulsion which – as already indicated – may have a very varied chemical composition. (Silver chloride, silver bromide, and a mixture of both are common, sometimes with a small quantity of silver iodide added.) The silver salt grains of this emulsion are incomparably smaller than those of a negative emulsion, and are never sufficiently large to make the print look grainy.

With glossy surfaced papers a final top coating of plain hardened gelatine is placed over the emulsion. This layer is very thin indeed. It is necessary, to protect the emulsion against pressure and friction, both of which tend to produce a black image on development, just as does exposure to light. Papers without such a supercoating are occasionally made for special purposes where intimate physical contact between the emulsion itself and a layer on another support with which the paper is sandwiched is necessary.

The plain hardened gelatine layer is not used with matt papers, but these have starch or other grains mixed in the emulsion to protect the latter against pressure and stress, as well as to make the surface appear matt.

PRINTING PAPER BASES

Printing papers come in a range of base thicknesses. Most widely used are single-weight and double-weight papers, the former of approximately 135 grams per square metre and about 0·2 mm thick, the latter about twice this weight and thickness. The exact specifications vary slightly with papers of different makes.

Single-weight papers are mainly intended for prints which are to be mounted later on. In big formats, paper of this thickness becomes a little difficult to handle in developing dishes, and may tear if pulled about too violently while wet. Double-weight prints are less likely to become crumpled when carried in wallets, and are also easier to manipulate during processing. In particular, a double-weight paper lies flatter on the enlarger baseboard and curls less during drying. Double-weight enlargements also are more rigid on their own if not mounted.

Still thinner paper bases, of weights between 40 and 80 grams per square metre, are used for special purposes, for instance to produce prints for airmailing. Document papers are usually thin based (between 70 and 90 grams per square metre); extremely thin bases (50–70 grams) have the advantage of being sufficiently translucent if prints are to serve as intermediate transparencies for mass copying (e.g. by the dyeline process). Machine-processing papers of this thinness may sometimes give trouble in roller processing units: if the paper is not sufficiently stiff to detach itself from the final squeegeeing roller, the print ends up wound round this roller and is usually impossible to remove without tearing.

Sometimes thinner paper bases are made specially translucent by varnish treatment (which incidentally also makes the paper waterproof). The translucency is due to the varnish filling up the pores of the paper structure and so reducing light scatter. Apart from technical uses, enlargements on translucent papers can be viewed either by reflected light or illuminated from behind. Enlarging papers also exist on a

translucent plastic base for this very purpose. While looking at the print the white plastic reflects sufficient light to act like a white base; on looking through it, the plastic evenly diffuses the transmitted light without any grain texture which would be associated with looking through a paper based print.

White opaque plastic supports have also been used for colour papers.

Plastic base is of course waterproof, which means that no processing solutions penetrate into the base. Many modern papers are plastic or resin coated and hence also waterproof. Such papers need shorter washing times (no chemicals have to be washed out of the paper) and dry much faster. They are thus particularly suitable for various rapid processing techniques and are more stable dimensionally since the paper does not expand on wetting. Waterproof paper bases are thus used also for prints from which accurate measurements have to be taken.

Translucent plastic film is also used for copying purposes, for instance, to make photo copies of engineering drawings. Such copies are perfect duplicates of tracings, and usually permit additional drawing work on the print surface.

Other non-paper bases include fabrics and metal foil. The former are useful not only to give an authentic linen textured surface, but provide a much tougher support than paper. They are thus handy for making giant mural-size enlargements; since the fabric can even be folded during processing, this makes the handling of big prints easier. After processing and partial drying, linen enlargements of this kind are easily flattened by ironing with a reasonably warm household iron.

Metal foil supports again have the advantage of perfect dimensional stability. The foil is usually thin aluminium sheet with a white pigment coating and the emulsion coated on top. This foil material is exposed and processed in exactly the same way as a bromide paper. Alternatively, metal foil may be laminated between layers of paper to produce a support of similar dimensional stability.

PAPER SURFACES

Papers are made in a wide range of different surfaces to produce a variety of aesthetic effects in the print.

Smooth Surfaces. All smooth-surfaced papers reproduce the finest details of a negative in the best possible manner. This applies especially to a glossy paper where the print is glazed after washing as described on page 347. This kind of finish is valuable in all scientific and technical prints, and is essential for prints which are to be used as originals for block making or other photo-mechanical processes. The main advantage of the glossy surface is here that it has the lowest surface scattering of light; hence it can yield the fullest blacks and therefore the greatest tone range in the print. In other words, whenever detail and full tone reproduction are important, a glazed print is the most suitable.

Semi-matt Surfaces are the next stage towards rougher surfaced prints. They are used for similar purposes to glossy papers, but the reduced shinyness tends to improve the appearance of prints for display and similar purposes where the picture is not to be reproduced further. Descriptions like "lustre", "velvet" etc. usually imply semi-matt paper surfaces. Portraits as a rule appear well on such paper.

A Matt Surface further improves the pictorial appearance of a print, and is specially valuable where large areas in single image tone are present.

All the above smooth papers are desirable for printing in small sizes; rougher surfaces need fairly big enlargements.

Grained Surfaces tend to suppress the detail of the image to some extent, depending on the particular type of graining present. The graining of the paper surface also tends to hide image graininess in the print, and can range from fine to rough; very coarse grained papers are useful only for large-scale prints. The actual emulsion surface is somewhat shiny.

Fabric Texture Surfaces. Certain unusual surfaces produced by manufacturers include patterns embossed on the emulsion surface to simulate silk, linen or other fabric textures. Typical descriptions are "rayon", "linen", "silk", "silk screen" and so on.

Rough ultra-matt papers, produced by one or two manufacturers, are very deep matt in character and give particularly dense black shadows with a velvet or charcoal-like texture. Such papers are exclusively intended for pictorial photography. Since their surface has no protective supercoating, the paper needs special care in handling to avoid stress and pressure marks.

THE BASE TINT

Paper bases are usually available in either white or cream, with sometimes ivory as an intermediate between the two. The choice of a base tint is primarily a matter of personal taste. Base tints should not clash either with the image colour of the print, or with the subject matter of the picture. A winter landscape, for instance, would not look well on cream paper; it would be better printed on a white base paper with a blue-black image colour.

As a tinted base reflects less light than a white one, such papers have a lower brightness range and are less suitable for originals destined for photo-mechanical reproduction. On the other hand, many current white-based enlarging papers incorporate so called "brighteners", i.e. white fluorescent pigments which increase the luminosity of the whites by reflecting ultra-violet rays as visible light.

Certain special papers (and types of enlarging linen) exist with yellow, green, red, etc. base tints with or without an added metallic tone (including silver or gold). These are intended primarily for decorative display, for instance of photo murals (page 467) and are suitable for enlargements of line originals, such as reproductions of maps etc., where the tinted background may look attractive. The low brightness range of such prints makes them less suitable for continuous-tone subjects.

COLOUR PAPERS

The structure of papers for colour prints and enlargements is largely similar to that of colour negative materials. The print material thus has three layers, each sensitive to light colours within one-third of the visible spectrum and each producing a dye image in a colour complementary to the sensitivity of that layer. Thus the blue-sensitive layer produces a yellow image after processing, the green-sensitive layer a magenta image and the red-sensitive layer a cyan (blue-green) image. This combination reconverts the inverted colour values of the colour negative into a positive image of colours corresponding more or less to those of the original subject.

There are two basic types of colour paper: positive papers for printing from colour negatives, and reversal papers for

printing from positive colour transparencies. They differ mainly in their sensitivity and colour balance characteristics, and in the fact that a positive colour paper is intended for straightforward positive development, while a reversal paper has to be processed by a more complex reversal procedure.

Within each group variations are however less than in the case of black-and-white print materials. Thus most positive colour papers are available in only one contrast grade, to suit negatives which have been processed under accurately controlled conditions. (Any deviation from such conditions and resulting contrast corrections would lead to distortions in the colour reproduction.) Reversal papers may be coated either on paper or white opaque plastic base.

The choice and handling of colour papers is subject to certain restrictions not encountered with black-and-white materials.

These cover on the one hand the selection of paper brand, and on the other its processing.

Firstly, makes of colour paper are sometimes "keyed" to certain makes of colour negative film. That is, the sensitivity of the individual paper layers is matched to the transmission characteristics of the dyes used in the negative film. The result is that the colour paper gives the most faithful colour reproduction and saturation when used to print negatives on the colour film for which it is designed. The colour paper can of course be used for printing from other types of colour negative as well, but the tone range and tone reproduction in the colour print may then sometimes be inferior.

There is no similar keying between reversal colour papers and colour transparency films.

Secondly, colour papers should generally be processed in the processing solution specially designed for them. This rule is almost absolute for reversal colour papers, but there exist certain so-called universal formulae for positive colour materials which are suitable for processing colour prints of different brands. The satisfactory working of such non-standard combinations should however first be checked by practical tests.

PRINTING PAPER PACKINGS

The numerous sizes, grades, surfaces and packings in which printing papers are supplied have always posed problems of

VIII – PAPER SHEET SIZES AND PACKINGS

Nominal Size: *Inches*	*Cm*	*Quantity Packings**
$1\frac{7}{8} \times 2\frac{3}{4}$	4·8 × 7·0	25, 100, 250, 1000
$2\frac{1}{2} \times 2\frac{1}{2}$	6·4 × 6·4	25, 100, 250, 1000
$2\frac{1}{2} \times 3\frac{1}{2}$	6·4 × 8·9	25, 100, 250, 1000
$2\frac{1}{2} \times 3\frac{3}{4}$	6·5 × 9·5	100, 250
$2\frac{3}{4} \times 4\frac{1}{2}$	7 × 11·5	25, 100, 250, 1000
$3 \times 4\frac{1}{8}$	7·5 × 10·5†	100, 250
$3\frac{1}{2} \times 3\frac{1}{2}$	8·9 × 8·9	25, 100
$3\frac{1}{2} \times 4\frac{1}{2}$	8·9 × 11·5	25, 100, 250
$3\frac{1}{2} \times 4\frac{3}{4}$	9 × 12†	25, 100, 250
$3\frac{1}{2} \times 5$	8·9 × 12·7	25, 100
$3\frac{1}{2} \times 5\frac{1}{2}$	9·0 × 14	25, 100, 250
4 × 5**	10 × 12·7	25, 100, 500
4 × 6	10 × 15	10, 50, 100, 250
$4\frac{1}{4} \times 5\frac{1}{2}$**	11 × 14	25, 100, 500
$4\frac{3}{4} \times 6\frac{1}{2}$	12 × 16·5	25, 100, 250
5 × 7**	12·7 × 18	25, 100, 500
$5\frac{1}{8} \times 7\frac{1}{8}$	13 × 18	10, 50, 100, 250
$5\frac{7}{8} \times 8\frac{1}{4}$††	14·8 × 21	100
6 × 8	15·3 × 20·3	10, 50, 100, 250
$6\frac{1}{2} \times 8\frac{1}{2}$	16·5 × 21·6	10, 25, 50, 100, 250
$7\frac{1}{8} \times 9\frac{1}{2}$	18 × 24†	10, 25, 100
8 × 10	20·3 × 25·4	10, 50, 100, 250
8 × 13††	20·3 × 33	100
$8\frac{1}{4} \times 11\frac{3}{4}$††	21 × 29·7	100
$8\frac{1}{2} \times 11$**	21·6 × 27·9	10, 50, 250
$9\frac{1}{2} \times 11\frac{3}{4}$	24 × 30†	10, 25, 100
10 × 12	25·4 × 30·5	10, 25, 50, 100
11 × 14**	27·9 × 36	10, 50, 100, 250
$11\frac{3}{4} \times 15\frac{3}{4}$	30 × 40†	10, 25, 100
$11\frac{3}{4} \times 16\frac{1}{2}$††	29·7 × 42	100
12 × 15	30·5 × 38	10, 25, 50, 100
13 × 16††	33 × 40	100
14 × 17**	36 × 43	10, 50, 125, 250
16 × 20	40 × 50	10, 25, 50, 100
20 × 24	50 × 60	10, 25, 50, 100

* Most American papers come in 500-sheet packings in place of 250, and in 250-packs in place of 100. Packs of 1000 sheets are generally available in contact papers only.

** American size, little used in Britain.

† Standard Continental metric size, little used in Britain.

†† Mainly document paper format.

economical production for the manufacturer and of the choice of paper for the photographer.

In the last three decades certain standardisation measures in the industry have at least simplified the labelling and packing of papers. Manufacturers now have code letters and figures which are consistent within a manufacturer's range and indicate the contrast grade, surface, base tint and paper thickness of a material.

Table VIII lists a rather large variety of nominal standard paper sizes marketed until about 10 years ago. More recently paper manufacturers have greatly cut down on the number of sheet sizes available, as international standards simplified the range. Officially metric sizes are specified.

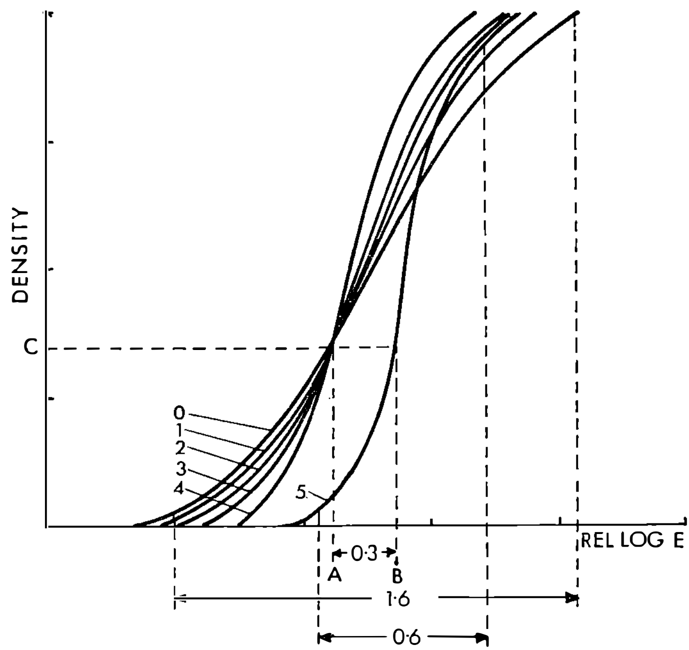
Printing papers are also available in rolls of various widths intended for commercial printing establishments and photo finishing laboratories using roll head printers.

STANDARDISING PAPER CHARACTERISTICS

Standardised paper formats arrived because of considerations of manufacturing and stocking economics. Some manufacturers are also beginning to standardise paper characteristics, such as speed and exposure range of different gradations.

It is useful to have different paper grades with the same speed, to allow a change from one paper grade to another without altering the printing exposure. This cannot always be extended to the whole range of grades, and the most contrasty grade may be slower than the others. Preferably this difference should be a fixed ratio – e.g. 1 :2. The matching point for the paper speed is usually in the middle of the tone range. (It is not too difficult to find one tone for which the exposure required matches on two different paper grades; the art is to match up the same tone in a whole paper range.)

This selection of a speed matching point is convenient for comparatively large scale printing operations where enlarging exposures are based on some form of integrating light measurement (page 275). Where exposure measurements are based on for instance highlight readings (measuring the darkest part of the projected image – page 264) a matching point near the bottom of the characteristic curves would at first sight seem more convenient. In practice this is more



The first five curves (corresponding to contrast grades No. 0 to No. 4) of this paper group are matched at the exposure level A – i.e. with such an exposure all papers yield the same density C. The most contrasty grade No. 5 has half the speed (i.e. the difference AB on the exposure scale is 0.3 log E units). The exposure ranges of these papers vary from 1.6 (a contrast range of 40:1) to 0.6 (contrast range 4:1). For this purpose the useful exposure range is taken to cover most of the curve except the extreme toe and shoulder.

difficult to achieve from the point of view of emulsion manufacture. The toe of a paper's characteristic curve is much more likely to be affected by batch-to-batch production variations as well as by storage conditions etc.

That is also one of the reasons why no speed criterion exists for papers and no speed numbers are quoted by manufacturers. The other reason is that speed ratings of sensitised materials only make sense where such materials are used under consistent exposure conditions. This is largely the case in the camera – which has more or less standard exposure controls (aperture, shutter speed) and is used in most cases for subjects of predictable brightness. In enlarging, exposure conditions depend on enlarger illumination and other factors which vary widely from one enlarger to the next.

In the past, paper grades and their nomenclature also varied greatly from manufacturer to manufacturer. More recently, makers have started switching to enlarging paper ranges with uniform differences in exposure range from grade to grade. A practical scheme is to vary the exposure range in fixed logarithmic intervals, e.g. 0.6, 0.8, 1.0, 1.2, 1.4 etc. for the range from ultra hard to soft (compare table VII on page 88). With older papers the interval was much greater between some grades and smaller between others.

While the names of paper grades show no similar standardisation – what one maker calls "normal", another may call "vigorous" or "special" – the use of a more or less international grade scale from 0 (softest) to 5 (extra or ultra hard) is spreading. These grade designations are related to exposure range (as shown in table VII on page 88), yet leave manufacturers free to stick to their own established nomenclature, however incompatible this may be with other makes.

The Enlarger

Now that we have looked at the starting and finishing points of the enlarging process – the negative and the printing paper – we have to consider in more detail the equipment used for the job, namely the enlarger.

When photographing the original subject, the camera usually records a large object on a greatly reduced scale as the image on the negative. When we enlarge the negative we aim at producing a large positive print from a comparatively smaller negative. So the process is turned round again, and we consider an enlarger a little like a camera working in reverse. The fact that the enlarged print rarely regains the natural scale of the original object does not alter the principle involved.

In its simplest terms, this is what is involved. We take an object (the negative) and use a lens to project its image on to a light sensitive surface (the enlarging paper). The paper is exposed to the image for a suitable time to yield – on development – a picture of (more or less) correct tone values.

Four important detail differences between camera and enlarging exposure conditions significantly determine both enlarger design and enlarging procedure. They are:

(1) The camera photographs an illuminated or self-luminous subject. The light distribution of the subject creates the photographic image. The negative used in the enlarger still requires light which the enlarger must provide. The light distribution is however given by the densities of the negative image, so the light provided should be as uniform as possible to translate the tone values of the negative reasonably faithfully into tones in the positive.

(2) In reducing a large object to a small image the camera works with a comparatively great lens-to-object distance and a small lens-to-film distance. Hence the camera can be compact. In the enlarger the lens-to-paper distance is generally appreciably greater than the lens-to-negative (here

object) distance. The enlargement moreover is comparatively big, and so the enlarger set-up – including provision for holding the paper at the appropriate distance from the enlarger lens – is necessarily bulky.

(3) From this it follows that while a camera can be made easily light-tight, it is neither easy nor convenient to enclose the image or printing side of the enlarger. It is more convenient to enclose the illumination system light-tight and use the whole enlarging set-up in a darkroom – all the more so since the room needs to be dark also for processing the print. (This principle is only abandoned in automated photo finishing equipment, where the whole paper supply and sometimes even processing arrangements are contained in a fully enclosed unit.)

(4) In an enlarger set-up both the object and the image are in two planes which most of the time are parallel. No depth of field problems therefore arise – unless the negative or positive image planes are moved out of parallelism. This can however provide a means of controlling image proportions.

THE PARTS OF AN ENLARGER

The main components of an enlarger are therefore:

(a) The lighting system, consisting of the light source itself and suitable means of directing an even flood of light on to the negative.

(b) A negative carrier to hold the negative flat below the lighting system.

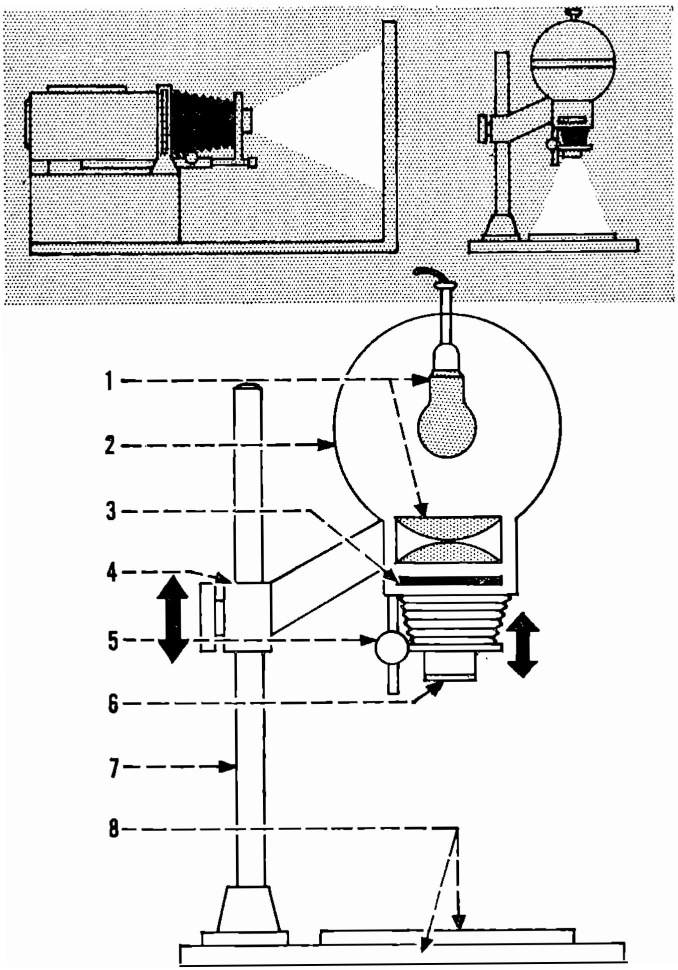
(c) The enlarger lens which projects the image of the negative on to the paper.

(d) A means of adjusting the lens for sharp focusing at different degrees of enlargement.

Items (a) to (d) are usually combined in the enlarger head assembly, often referred to as the lamphouse. Strictly speaking the lamphouse is however only item (a).

(e) A surface to hold the enlarging paper firmly at the correct distance from the lens and parallel to the plane of the negative. This is generally an easel or baseboard.

(f) A system for adjusting the distance between the



Enlargers can have two basic layouts, horizontal (*top left*) and the more common vertical (*top right*) construction. See also page 120.

Bottom: The principal enlarger components are: 1, lamp and condenser; 2, lamp house; 3, negative carrier; 4, supporting arm (adjustable for different magnifications); 5, focusing movement (adjustable for maximum sharpness); 6, lens; 7, column; 8, baseboard and paper holder.

easel and the lens for different degrees of enlargement, while keeping both accurately lined up.

This basic design of an enlarger can be carried into practice in quite a number of different ways. In the first place it is however necessary to distinguish between two general classes of instrument – horizontal and vertical. Both have advantages and drawbacks, but to date the vertical arrangement is more popular.

Horizontal Enlargers, in which the distance between the lens and easel can be varied almost indefinitely, have a very wide range of service. Their chief drawbacks are that they necessarily take up a good deal of room and that the sensitive paper must be attached to a vertical surface. For these reasons horizontal enlargers are only popular among specialised workers in advertising photography, or in the darkrooms of large photo-finishing firms where reduction, full-size copies and enlargements of practically any size must be possible at short notice. In a horizontal enlarger the head assembly and the easel move along a set of rails or a bed laid out in the manner of an optical bench. Since the whole arrangement is firmly supported, horizontal enlargers are more rigid where very large negative and print sizes are involved, and where rigidity is of particular importance.

Vertical Enlargers carry the whole set-up arranged along a vertical optical axis. They therefore take up relatively little space and have the advantage that the printing paper is placed on a horizontal baseboard for exposure. They are rapid and simple to handle in practice, but can only provide a limited range of enlargement. The enlarger head assembly in this case is mounted on a vertical column which in turn is fixed to the baseboard. This arrangement is therefore less rigid and needs special stabilising constructions, especially where big enlargers are involved. A heavy head assembly may need a more or less complex mechanism to permit accurate movement up and down the column. Sometimes the easel is movable as well. In most vertical enlargers the lamphouse is at the top, and the easel at the bottom.

Inverted Vertical Enlargers reverse this arrangement and have the lamphouse and negative carrier at the bottom, and the easel on top. The latter is in this case a plane glass surface on which the paper is placed, emulsion side down. This often makes manipulation even easier, but the enlarging

range is rather restricted. For with the easel at a comfortable working height, there is not a great deal of room underneath for great lens-to-paper distances. Such designs are therefore popular in mass printing enlargers used in photo-finishing, where only limited magnifications are called for. Copying cameras used as enlargers may also follow a similar layout.

Let us now examine the individual enlarger elements in greater detail.

THE PROBLEM OF ILLUMINATION

The chief necessity in an enlarger is that of illuminating the negative so that a satisfactory bright image is obtained on the paper. Since this image must be evenly illuminated all over, the negative needs equally even illumination.

A negative cannot be illuminated evenly just by placing a tungsten lamp behind it. With such arrangement the enlarged print will be light in the centre and dark towards the edges. But if a sheet of opal glass is placed between the lamp and the negative, all the light passing through is scattered or diffused in every direction. This makes illumination over the negative surface much more even than before. It would still not be fully uniform, for the edges of the opal glass are further from the lamp than its centre. To overcome this it is necessary either to have the lamp at some distance behind the opal glass or to use a reflector as well behind the lamp. Such a reflector should be approximately spherical in shape to spread the light from the lamp itself as evenly as possible.

DIFFUSED LIGHT

These points lead us at once to one of the possible types of lighting system in an enlarger: illumination by diffused light. This system is used in some low-priced enlargers and is perfectly satisfactory in practice. However, since the diffusing surface radiates light uniformly in all directions through the negative, only a comparatively small proportion of this light actually reaches the enlarger lens to be projected on to the paper. Hence the light efficiency of a diffused illumination system is low and such an enlarger needs appreciably longer printing times for a given negative and given degree of enlargement than for instance a condenser enlarger (see page 126).

As we have seen, a single lamp behind a diffusing screen – even if it is an opal lamp (page 136) – is not very efficient in uniformly illuminating the negative. One way of increasing the efficiency is to use a thicker opal glass – but that cuts down the light enormously. The usual diffusing surface is flashed opal – glass with a thin opal layer rather than solid opal throughout.

There are various possibilities of evening out the illumination especially over large areas in enlargers for big negative sizes. The simplest is to use several lamps, distributed above the diffuser so as to cover the latter uniformly. One practical problem is that the lamps must all be of exactly the same strength and – when the enlarger is used for colour work – of the same colour quality. Matching lamps is not as easy as it sounds, since bulbs of nominally the same light output and voltage may vary noticeably due to manufacturing tolerances. Also, the light output of a bulb drops during its burning life. For this reason a set of enlarger lamps should be replaced together. Putting one new lamp with two or three older ones well through their burning life may easily lead to spots of uneven brightness.

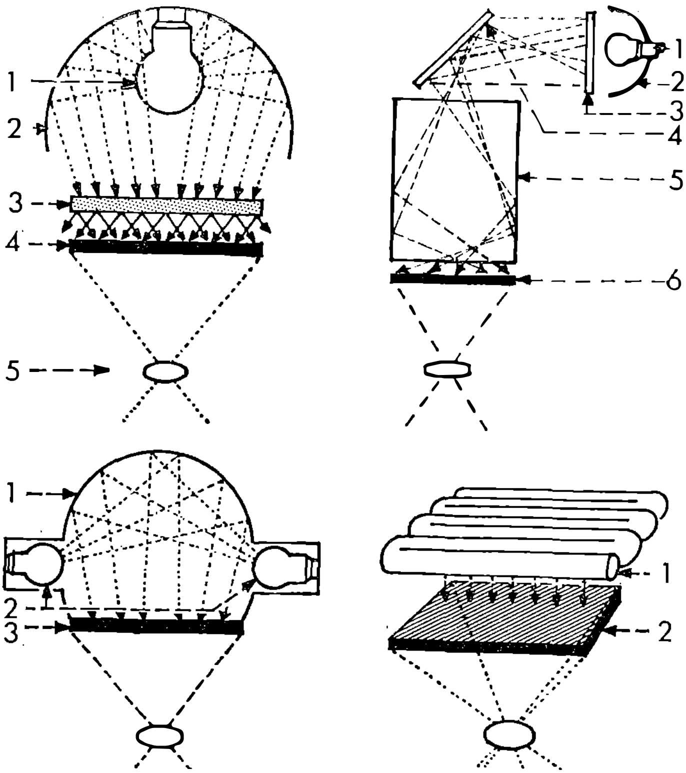
INDIRECT DIFFUSED LIGHT

The problem of even negative illumination can also be solved in a second way, still using diffused light. The principle is analogous to "hidden" room lighting: the lamp does not illuminate the room directly, but throws light on to the ceiling which scatters it over the area below.

In a similar manner, the lamp in an enlarger can be arranged to illuminate the back of the lamphouse rather than the negative. There are various ways of doing this, but all have in common a large and usually spherical white diffusing surface behind the negative. This surface is then lit by one or more lamps from a position where they can throw no light on a negative itself.

Diffusing reflectors or light integrators of this kind require a careful design of the reflecting surface to ensure really even illumination. The ideal form is an integrating sphere where a lamp shining through an aperture in the side completely evenly illuminates the whole of the inside surface by multiple reflection. If part of this surface is cut away to accommodate the negative carrier, the negative

DIFFUSED ENLARGER ILLUMINATION



Top left: The most straightforward method of uniform illumination is to place a flashed opal glass diffuser above the negative, and surround a large lamp with a white reflector to distribute the light most evenly. 1, lamp; 2, reflector; 3, opal diffuser; 4, negative; 5, lens.

Bottom left: The integrating sphere uses a large matt white illuminated sphere with only reflected light reaching the negative. 1, sphere; 2, lamp; 3, negative.

Top right: As an alternative to an integrating sphere some enlargers use a mixing light box. 1, lamp; 2, reflector; 3, diffuser; 4, mirror; 5, integrating light box; 6, negative. The integrating box may be interchangeable for different negative formats.

Bottom right: A cold cathode tube provides even illumination through the large area of its light source, obtained by coiling a fluorescent tube into a large enough area to cover the negative. 1, cathode grid; 2, negative.

receives similarly even illumination. To provide adequate intensity of illumination, modern diffused-light enlargers of this kind frequently use tungsten-halogen lamps. These demand more efficient cooling (and blower cooling with larger formats).

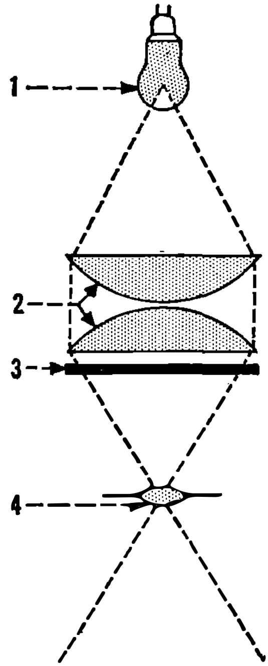
Such diffused-light arrangements are used in many colour enlargers where colour printing filters may be placed between the light source and the integrating sphere. Alternatively, the latter is replaced by a reflector arrangement and a mixing box or tunnel, with highly reflective internal surfaces, between the light sources and the negative carrier. Colour printing filters may then be located at the top of the tunnel.

If the mixing box is interchangeable, alternative boxes of different size can concentrate the light on different negative format's.

COLD CATHODE LIGHTING

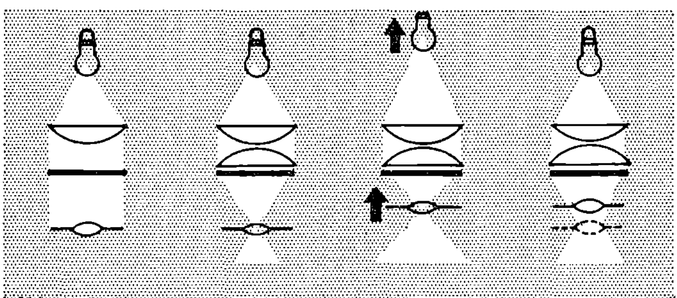
A logical extension of using a large light source (or a number of light sources for uniform diffused illumination) is to cover the whole area immediately above the negative in the enlarger with a suitable lamp. One type of lamp available for this purpose is a cold cathode grid. This is essentially a mercury vapour fluorescent lamp in tubular form. The tube may be bent either in a folded grid or as a spiral. Or, a series of tubes can be assembled in front of trough shaped reflectors. In either case the cold cathode grid assembly acts as a uniformly bright surface and is particularly suitable for large negative formats.

Cold cathode lighting has a number of further advantages. The light is, as the name implies, practically cold, so that the lamphouse need be no more than a shallow box with no ventilation or cooling requirement. Further, the light is highly actinic – i.e. rich in short-wave radiations at the blue-violet and blue end of the spectrum to which enlarging papers are particularly sensitive. (Tungsten lighting is comparatively inefficient in this spectral region.) Hence cold cathode illumination is much more effective for enlarging purposes (but not suitable for colour enlargers), which means that even with a medium power unit the useful light output makes up for the loss of light to which diffused illuminating systems are subject.



Right: In a condenser enlarger the light from a point source is focused through the negative into the enlarger lens. This way the maximum light from the lamp is utilised.

1, point source lamp; 2, condenser lenses; 3, negative; 4, enlarger lens.


A B C D

With a parallel beam of light (A) most of the light passing through the condenser would be lost. For maximum efficiency the light should be focused exactly in the lens plane (B); the lamp-to-condenser distance must be adjusted whenever the lens is refocused (C). A compromise solution (D) is to focus the light permanently at a point somewhat beyond the enlarger lens, corresponding to the position of the lens at low magnifications.

DIRECT ILLUMINATION WITH A CONDENSER

A more efficient method of illuminating a negative uses a lamp and a condensing lens. The lens collects the light from the lamp and concentrates it evenly on the surface to be lit up.

The principle is similar to that of a spotlight or even of a pocket torch. Here the lamp filament is placed at the focus of the condensing lens, so that the beam emerging from the latter is practically parallel.

In utilising such an optical system in an enlarger, a parallel beam of light is not the ideal one. The function of the condenser lens there is not only to throw an even beam of light on to the negative below it, but also to make all the light it has collected from the lamp pass through the projection lens and thus to the sensitive paper on the easel.

However, only the light rays passing through the enlarger lens can produce an image on the easel. The lamp is therefore placed in such a way that the light beam leaving the condenser converges until it comes to focus on the actual centre of the enlarger lens. The negative is placed within the beam sufficiently close to the condenser that the whole negative area is within the cone of light.

With this type of optical system the most efficient possible use of the light is obtained when the source itself is in the form of an extremely small point. In this way no light is lost between the lamp and the lens.

Condenser illumination, especially with a point source, has a number of advantages, but also a few drawbacks. The main advantage is that the image on the paper is very brilliant and very even. This system of condensed point-source illumination is therefore widely used for projecting transparencies and cine films.

The drawbacks for enlarging arise first from the need to make an enlarger adjustable, and secondly from the nature of the negative itself.

The shape of the light beam obtained from a condenser system depends on the relative positions of the lamp and the condenser. To obtain a beam converging on to the centre of the lens, the lamp must therefore be at a specific distance behind the condenser. Bringing the lamp nearer makes the beam less convergent – it would focus on a lens farther

away from the front of the condenser. If the lamp is farther away, the beam becomes more convergent.

As the distance from the lens to the negative has to be varied to obtain different degrees of enlargement, these would also require an adjustment of the lamp position to obtain maximum efficiency whenever the enlarger magnification is changed. For this reason it is more usual to focus the cone of the light transmitted through the condenser on a point beyond the lens, so that the section of the cone of light at the lens plane is somewhat wider than the lens itself. This wastes some light, but allows the lens to be focused over a wide range of magnifications without any need for readjusting the lamp behind the condenser.

THE CALLIER EFFECT

Ideally an enlarger should not modify the tones of the negative placed in it. The effect of the enlarger on the reproduction of negative tones can be easily tested by using a step wedge (page 63). This wedge, if made as a series of silver densities, acts as a kind of imitation negative with a standard set of tones. When enlargements are made from this wedge in different enlargers, the scale of grey tones obtained on the paper should be identical in gradation.

When tested in this way, an enlarger with condenser illumination will be found to give considerably higher print contrast than a diffused light enlarger. At the same time the slightest scratch or other flaw in the negative shows up very plainly in the enlargement.

These effects are due to the fact that the optical properties of a negative vary over its area. In the clear part of the shadows, light passes through the emulsion as it does through a glass window. Where however a silver deposit is present, the light is not only absorbed but also scattered in all directions. At any point of the negative where silver is present as a black deposit, the optical quality of the emulsion is thus similar to that of a piece of ground glass or other turgid medium.

If the negative were replaced by a sheet of glass ground in some parts and clear in others, a similar state of affairs would result. The rays of light passing through the clear portions go directly through the projection lens and thus to the paper. Where however the glass is ground, a propor-

tion of the light is scattered back. A second portion is absorbed by the glass, just as it would by the silver image. A third – and larger – portion is scattered in every direction on the far side of the ground glass from the condenser. Only a small proportion of the scattered light reaches the projection lens and passes through it to reach the paper; most of it merely falls on the inside of the enlarger housing and is thus lost. Therefore the part of the image on the paper corresponding to the ground section of the glass is darker than the image of the clear glass portion.

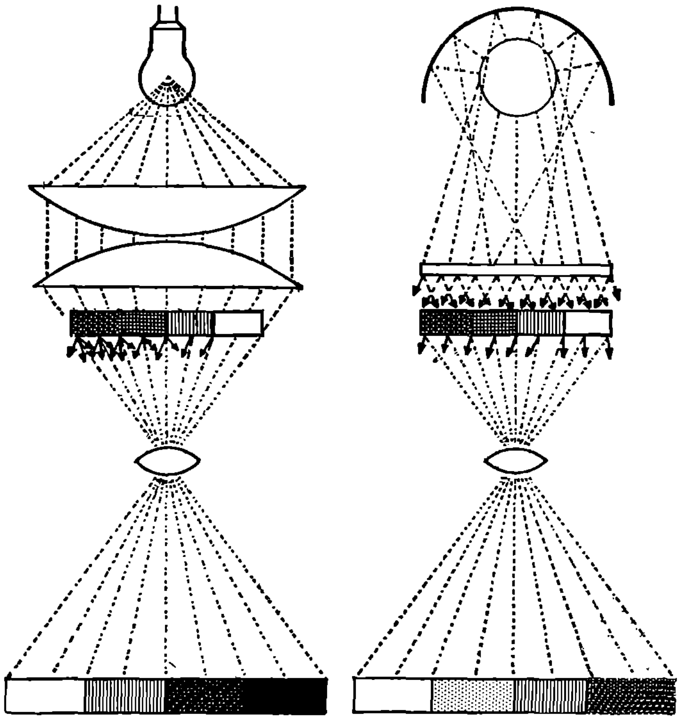
A negative silver image produces the same kind of scattering as the ground glass in the above example. The effect is usually called the Callier effect. The fact that the silver scatters and loses light implies that the developed enlargement is considerably harder in contrast than the original negative. Small scratches and blemishes on the emulsion scatter light as much as the silver deposit itself and so show up far more clearly in the enlarged print than they appear on visual examination of the negative.

No selective scattering of this kind takes place with diffused enlarger illumination, since the rays falling on the clear areas of the negative are already scattered in all directions. In effect, the silver deposits act as a diffusing medium, and it is the higher efficiency of light transmission of the clear areas (not just their lower density) which causes this increase in contrast.

The degree of scattering depends both on the enlarger and on the nature of the image. To take the second point first, coarse grained silver images scatter light more strongly than fine grained ones. Also, the dye images of colour negatives, being transparent, scatter light far less.

For a given negative image the degree of scattering is thus determined by the lighting system of the enlarger itself. It can be determined numerically as the Callier factor. To do this requires a step wedge, two selected steps of which are measured in a densitometer. This will give density values which might for example be 0·2 for the lightest step and 1·3 for a dark step – a difference of 1·1. The step wedge is then placed in the enlarger and the brightnesses of the corresponding steps measured on the baseboard. This can be done with an enlarging exposure meter (page 263), in which case the exposure times have to be converted into

THE CALLIER EFFECT



Left: When the highly directional beam of light from the condenser passes through the negative, the silver grains of the image scatter some of this light. The higher the silver density, the more light is lost by scattering. Dark image portions projected on the baseboard become even darker, while thin negative areas with little silver scatter little or no light. Hence the negative contrast is apparently increased. This is the Callier effect.

Right: With a diffused-light enlarger the light reaching the negative is already scattered in all directions; hence high negative densities do not scatter any more than the thin negative portions and the contrast of the projected image is lower.

logarithmic values. If the exposure times measured for the same two steps on the baseboard are say 4 seconds and 86 seconds respectively, their ratio – 1:21·5 – corresponds to a logarithmic exposure range of 1·45. This logarithmic value, divided by the density difference between the steps as measured in a densitometer (1·1) gives the Callier factor – in this case 1·32.

The Callier factor is of importance where negative densities are measured separately before enlarging to determine enlarging exposures and especially paper grades required for a given negative (page 270). Where however the enlarged image is only measured on the baseboard, the exposure measurement automatically allows for the Callier factor.

A further aspect of condenser illumination, as compared with diffused light, is the change of resolution in the enlarged image. This is closely related to the degradation of contrast with diffused lighting. Due to the small but nevertheless finite aberrations that are always present in an enlarging lens, the light from a transparent area of the negative slightly spreads out beyond its proper boundaries. If two such small areas are close together, the light spilt over from each may add up in what should be the clear space between them, and these two areas may then not be distinguishable – i.e. not resolved. When light is also scattered from the area between them, as is the case with diffused lighting, the two areas have to be farther apart to avoid the light spilt over from each from adding up. Hence the limiting resolution of an image illuminated by diffused light is lower, and for the finest detail reproduction condensed illumination is advisable.

Condensed light, therefore, though ideal from the point of view of image brightness (permitting short exposures), evenness of illumination and resolving power, is unsatisfactory in the contrast effect it produces. Fortunately a simple remedy is available for the defects both of condensed and diffused light by using an optical system which combines the principal features of each.

SEMI-DIFFUSED ILLUMINATION

If the partially ground glass mentioned on page 127 is placed in an enlarger using diffused light, the light reaching

the clear and unground portions is already scattered so that further scatter on the part of the ground portions cannot cause an extra loss of light. Thus in a diffused-light enlarger there is little change of contrast. In fact there is always some loss of contrast since light passing through the clear portions of the negative is scattered and thus fogs the highlights in the enlargement. So if a compromise between these two general types of illumination can be found, it may be possible to combine the advantages of both with the effect of neither.

This compromise is obtained by introducing a diffusing medium into the condensed light optical system between the lamp and the condenser. The result is then semi-diffused light. The majority of commercially available enlargers use this principle. The design only has to ensure that the degree of diffusion is not so great as to nullify the effect of the condenser.

The most common arrangement employs an opal lamp in conjunction with a condenser. The opal bulb of the lamp here provides the necessary diffusion of light. There is admittedly some loss of light in the opal bulb (about 5 per cent) and a rather greater loss due to the fact that the light source is no longer an ideal point source. But the exposures required are far shorter than those needed with a diffused-light instrument.

In principle the condenser here directs the light from what is more or less a diffused source into the enlarger lens, so reducing the loss of light as compared with a pure diffused-light enlarger. While this does not require an adjustable enlarger lamp for purposes of refocusing the light source at different magnifications, such enlargers do provide a lamp adjustment for evening out the illumination. For the uniform lighting of the negative area does depend on the lamp position relative to the condenser. This is usually adjusted by trial and error with a given enlarger lamp, and the setting can be made by examining the illuminated area – without a negative in the carrier – on the enlarger baseboard. Visual observation already shows whether the centre of the image area is brighter than the edges or not. For more accurate estimation an exposure meter or an enlarging photometer (page 263) can be placed in turn in the centre and at the edges of the illuminated field, and the readings compared.

The enlarger lamp is adjusted until the meter measurements are reasonably uniform. The setting of the enlarger bulb can then be fixed, and needs no changing unless a larger or smaller bulb is substituted.

An alternative arrangement of condenser and diffusion uses a diffusing screen underneath the condenser, between it and the negative. This is however in effect a fully diffused-light enlarger, the condenser only spreading the illumination evenly over the diffuser area.

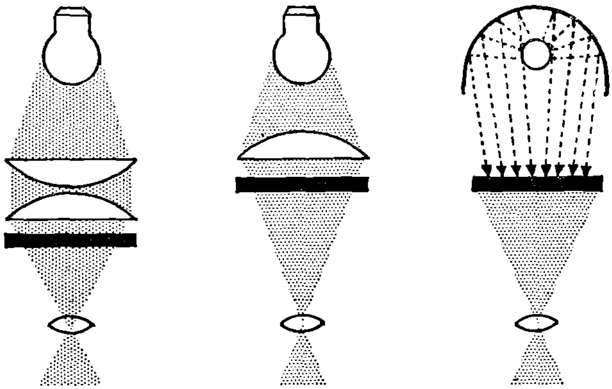
CONDENSER ARRANGEMENTS

Condenser enlargers – with a point source or with semi-diffused illumination – generally use a pair of plano-convex condenser lenses, with the convex sides facing each other and the flat sides outside. The condenser must have a diameter of at least the diagonal of the largest negative size employed; generally a slightly larger condenser is used, so that the negative can be placed a little way below the condenser in the converging light beam. This avoids reproducing dust and condenser scratches in the projected image.

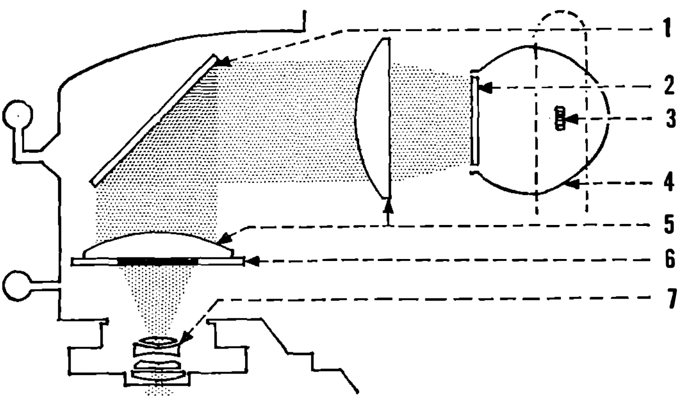
The focal length of the condenser is then a little less than the focal length of the enlarging lens. For enlargers taking different negative sizes and working with interchangeable lenses the condensers should strictly speaking also be interchangeable. This is important mainly in lighting systems with a point source lamp; with semi-diffused illumination a re-adjustment of the lamp position in the lamphouse is usually sufficient for even illumination with lenses of different focal lengths.

A number of alternative condenser layouts are also used. Thus there is no real need to have the convex sides of the condenser lenses facing each other; the plane sides could both point in the same direction – towards the negative. Miniature enlargers frequently use one condenser lens only – either biconvex or plano-convex, with the flat side towards the negative. The flat side may even be used to hold the negative flat in the carrier, and may be specially treated to avoid Newton's rings (page 161).

A single condenser is possible with small negative sizes, since a single lens of the required diameter can here achieve the necessary focal length without becoming too thick. The drawback of very thick condenser lenses is not only a



With a large light source and a condenser system there is still some scattering so that the enlarger has characteristics both of diffused light and condenser arrangements (*left*). Many miniature enlargers achieve the same result with only one condenser lens (*centre*). An alternative system is to use a parabolic reflector behind the lamp and no condenser (*right*).



Projection lamps are used in some enlargers. As they have to burn upright, a mirror is also necessary. 1, mirror; 2, diffuser acting as the light source; 3, lamp filament; 4, reflector; 5, condenser lenses (the mirror is placed between the two lenses where the light beam is parallel); 6, negative carrier; 7, enlarger lens.

considerable degree of spherical aberration (which makes it difficult to obtain really even illumination) but also expense and the danger of cracking due to heating in the enlarger lamphouse. This is a significant factor with very large condenser diameters for big negative formats, and is one reason why diffused lighting is more usual there. Alternatively, a condenser system of three lenses can be used.

To reduce weight slightly, condenser lenses are sometimes cut down to a square, i.e. the area needed to actually illuminate the negative.

The condenser lenses themselves are optically ground and polished lens elements. In very cheap enlargers moulded condenser lenses have occasionally been employed. These are certainly cheaper to produce, but are generally unable to illuminate the negative uniformly, even in a semi-diffused light enlarger. Plastic Fresnel condenser lenses have also been tried – to reduce both weight and thickness – but are very difficult to make with sufficient accuracy. Again, illumination is not even (especially towards the edges) and the Fresnel ring pattern may become visible in the print.

REFLECTORS

A concave mirror has properties similar to those of a lens and in many cases can take the place of a lens – for example in the construction of large floodlights where the concave reflector replaces a large and naturally costly lens.

A concave mirror can similarly replace the condenser in an enlarger. This is specially useful in apparatus designed to take large negatives and is another way of getting round the difficulties and expense of using very big condenser lenses.

The path of the rays in a concave mirror system is analogous to the path of the rays when a condenser is used. The light source is placed a little outside the focus of the mirror, so that the rays of the mirror converge on to the projection lens. The negative receives not only the light reflected from the mirror, but also direct light from the source.

A mirror reflector can also be used with condenser enlargers to utilise the light from the lamp more efficiently. The lamp filament is in this case placed at the radius of curvature of the mirror. All the light which would have been lost behind the lamp is then reflected back through the

location of the filament on to the condenser in the same way as direct rays from the filament. Such a mirror can increase the light output of the system two- to four-fold and is particularly useful when battery-powered low-voltage light sources have to be used, such as motor car headlamp bulbs. In a normal enlarger with mains illumination this increased light intensity is not usually necessary and may even be an embarrassment because it makes enlarging exposures too short at low magnifications.

A reflector of this kind is also useful if a projection lamp is used as the light source, as in the arrangement shown on page 133. Here a diffusing screen in front of the lamp becomes the real light source for the enlarger. The spherical reflector surrounding the lamp ensures that the maximum light flux is concentrated on this diffuser. Since such projection lamps usually have to burn upright with the cap down, they cannot be arranged in the usual position of the enlarging bulb. A mirror is therefore used between the condenser lenses to bend the light beam downwards through the negative. Such mirror arrangements – with the mirror either between the condenser lenses or between the lamp and the condenser – are widely used also in many modern enlargers with opal lamp or point source illumination. Apart from permitting better heat dispersal (especially when used in conjunction with diathermic mirrors – see below), such a layout also makes the enlarger lamphouse more compact in height and makes reflex viewing systems for copying feasible (page 197).

Most mirrors and reflectors reflect heat as well as light, and this concentration of heat on the negative for any length of time may be harmful. While ventilating arrangements can reduce the temperature of the lamphouse and the negative stage, they cannot remove the concentration of radiant heat. The modern trend in employing reflectors is therefore to select so-called diathermic mirrors which reflect a high proportion of visible light but let most of the heat rays (up to 90 per cent) pass through. In a projection lamp arrangement (page 133) either the lamp reflector of the mirror between the condenser lenses could be a diathermic one.

In a semi-diffused light enlarger a reflector generally surrounds the light bulb. The reflector is here little more than a white dish-shaped diffusing surface; its purpose is

to enlarge the effective area of the light source. The amount of light redirected towards the condenser is however comparatively small.

LIGHT SOURCES FOR ENLARGERS

The most common light source in simpler enlargers is the opal lamp (page 122). This has a bulb envelope with a flashed opal layer. The lamp acts like a light source of uniform brightness of the diameter of the bulb.

The opal lamp is substantially different from the normal pearl lamp which is not uniform in brightness, but distinctly shows the shape of the filament. Pearl lamps thus are not suitable for enlarger illumination, except possibly in a diffused light enlarger using a set of moving lamps (page 122).

The opal lamp chosen should be specially intended for enlarging. The main characteristic of such lamps is that they carry the imprinted maker's name (and voltage and power indication) on the side of the bulb instead of on the top, to avoid projecting this imprint. Sprayed enlarger lamps were at one time available as a substitute for opal bulbs.

Opal lamps are available in powers from 60 to 250 watts. The higher powered lamps are useful where a low-sensitivity paper must be used for enlarging, and also in colour enlargers where the filtering required increases exposures.

There are a number of possibilities for increasing the intensity of the light without obtaining a very powerful lamp. We can in the first place overrun the lamp by using it on a somewhat higher voltage than that for which it is intended – at the cost of reduced burning life. Commercially available high-intensity tungsten lamps for enlargers are slightly overrun in this way.

Much brighter light is available from lamps of the heavily overrun type, normally used for photographic lighting. These give six to ten times as intense light as a normal enlarger bulb. Here, too, the high intensity is only obtainable by reducing the burning life of the lamp. It is however comparatively simple to use a resistance in circuit with the lamp, so that it burns at low intensity for focusing and at full power only for the exposure time itself.

Projection lamps (page 133) used with an appropriate lighting system also provide a greatly superior light intensity.

Tungsten-halogen lamps, widely used in projectors, are

also finding their way into enlargers. They are generally run from 24 volts (requiring a transformer) but yield nearly twice as much light as mains voltage tungsten lamps of similar nominal power – and constant light output and colour temperature (significant for colour enlarging). The very compact lamp is ideally suited for point source condenser enlargers, but can also be used in diffused light enlargers with integrating sphere (page 123). Usual wattages are 150 or 250 watts; in large-format diffused-light enlargers tungsten-halogen lamps with a total power up to 2000 watts may be used. Special points apply to cooling (page 140).

High pressure mercury arc lamps are sometimes used in enlargers intended for very high magnifications (for example photo murals) and in systems designed for use with papers of low sensitivity. They utilise an arc struck between tungsten electrodes in a small quartz tube containing mercury vapour. The tube is enclosed in a partly evacuated outer glass envelope to limit the heat loss and maintain the pressure at the arc. The luminous efficiency of the lamp is very high (it can give thirty times the light intensity of an ordinary filament lamp using the same current) but the system requires special adaptation of the enlarger. Once the lamp is switched off the arc cannot be struck again until the lamp has been allowed to cool for several minutes. The mercury arc must be operated through a choke.

Another light source of extreme intensity is the pulsed xenon lamp. This is similar in principle to an electronic flash tube flashing at a high rate. Such a lamp needs considerable control equipment and light sources of this kind are used exclusively in enlargers for graphic arts applications, but not in normal print making.

Gas discharge tubes of the fluorescent lamp type also need special control equipment – including a choke – but can be switched on and off at any time. Such tubes are used as large diffused light sources in cold cathode lighting (page 124). This does not mean that no heat is produced at all, but the efficiency is so high that a unit of 80 or 100 watts (the usual size) provides a very high light output and the generated heat is low enough to be quickly dissipated.

Cold cathode tubes are also available as conversion units which can be used with most types of commercial enlarger.

These units are virtually lamphouses, made in various sizes and simply replace the normal lamphouse.

The life of a cold cathode tube is considerable. Actually it never ceases to work, but the light output drops after about 6000 hours, and the tube should then be replaced.

OTHER LIGHT SOURCES

For use in districts where no mains electric supply is available, there are enlargers working with motor car headlamp bulbs run off an accumulator. A car battery – if a car is available – is of course equally suitable. The lamps operate on 12 volts (sometimes 6 volts) at 30 to 48 watts.

The headlamp bulb has virtually a point light source, and enlargers designed for this type of lighting have condenser units, usually with an added reflector behind the bulb, to make the most of the light output. Under these conditions enlarging exposures obtained are of about the same order as with a normal mains lamp.

If the increased contrast, due to the Callier effect (page 127) is not wanted, an opal glass sheet between the lamp and the condenser provides a semi-diffused lighting system. This also reduces the light intensity, but that may be overcome by overrunning the lamp. This may mean using a battery of higher voltage than the lamp is designed for, and again shortens the life of the lamp.

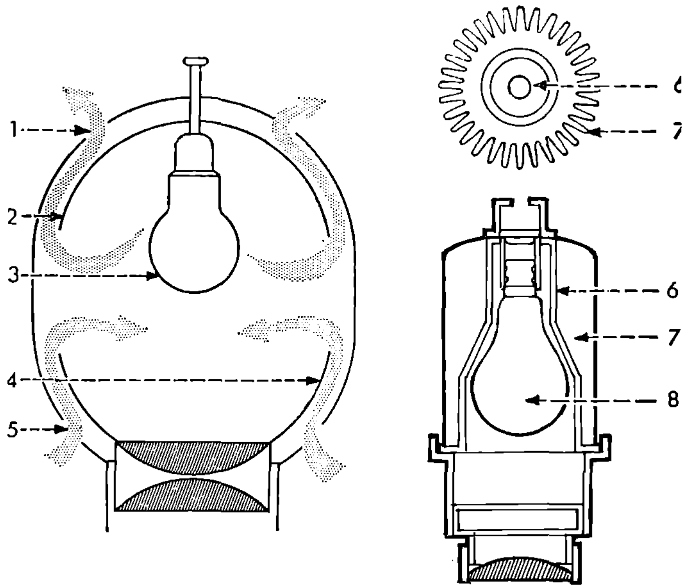
Generally about 10 per cent overrunning gives a light intensity not far below the intensity of a normal enlarging lamp and will not too seriously shorten the burning life. The useful limit of overrunning is about 25 per cent above the rated voltage; beyond that the lamp behaviour becomes unpredictable.

Non-electric light sources can also be used for enlarging – for example coal gas, acetylene and other gas burners, as well as mantle-type paraffin lamps. Such light sources require direct ventilation to remove the combustion fumes from the enlarger. This is provided by a ventilating chimney in the housing, and non-electric light sources are largely confined to horizontal enlargers.

COOLING

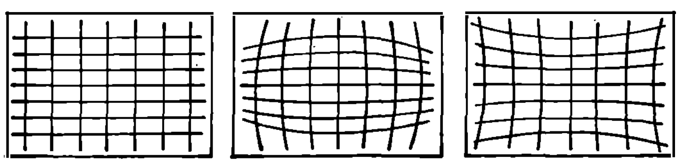
Lamps, especially tungsten filament types, generate far more heat than light. This heat must be removed from the lamp-

VENTILATION



Since enlarger lamps produce not only light but even more heat, the lamphouse needs some cooling. A common system (left) uses baffles and ventilation openings. 1, upper ventilating holes; 2, light baffle (also acts as reflector); 3, lamp; 4, lower baffle; 5, air inlet through lower ventilating holes. A radiation-only system (*right*) has the lamp 8 inside a close-fitting heavy casting 6 of high thermal capacity, equipped with fins 7 to radiate away the heat.

LENS DISTORTION



To test the enlarger lens for distortion, a rectangular line grid can be placed in the negative carrier, Without distortion the lines on the projected image should be straight right into the corners (*left*). If the lens has barrel distortion (*centre*) the lines bend inwards near the corners. Pin cushion distortion results in the lines being pushed outwards at the corners (*right*).

house of the enlarger to avoid over-heating of the condensers and negatives in the carrier.

An enlarger – unlike a projector – is not left switched on continuously for long periods. But it should still be designed to permit indefinite running with the lamp switched on and without risk of damage. An exception might be made in the case of overrun lamps operated through a voltage dropping resistance during setting up and focusing.

Cooling of the enlarger lamphouse takes place by radiation and by convection. The efficiency of heat radiation depends largely on the size of the lamphouse and its outside finish. For this reason enlarger lamphouses are usually finished in black – a black surface is the most effective radiator.

The lamphouse should also be large enough for the power of the light bulb used.

In diffused-light enlargers utilising an integrating sphere (page 124) the lamp compartment proper is comparatively small – otherwise the enlarger head dimensions would become enormous. The lamp housing itself may in this case be fitted with fins to increase the radiating surface and also to carry heat away from the housing by convection.

Radiation lamp houses (page 139) dispense with ventilation altogether. Instead the lamp housing is a heavy but compact casting of high heat capacity that hugs the lamp and dissipates its heat via external fins. In use, this gets too hot to touch.

The fact that a lamphouse gets hot does not necessarily indicate poor design; a small lamphouse especially has to dissipate a lot of heat. But it is wise in such a case to fit a heat filter between the lamp and the condenser. This filter should be slightly spaced from the top condenser surface, and not in contact with it. The heat filter is particularly important with colour enlargers, since the dyes of colour negatives may be affected by excessive heat and because some colour papers are sensitive to infra-red radiation which may interfere with colour control.

Tungsten-halogen lamps must not be cooled too much, as their efficient operation depends on keeping the bulb envelope hot. The negative carrier and optical system however need protection against this heat. Enlarger designs similar to that shown on page 133, bottom, are well suited to this type of lamp, especially if the lamp reflector and deflecting mirror are diathermic (i.e. reflect light but transmit heat).

VENTILATION AND BLOWERS

A second way of cooling the lamphouse is by carrying heat away with an air current. Nearly all enlarger lamphouses have ventilation openings – one set around the base and another set around the top. The cool air then enters at the bottom, while hot air emerges at the top. The air vents must be adequately baffled, so that only air and no light can get out of the lamphouse.

Enlargers with high-power lighting, and also with certain types of high intensity lamp need forced cooling. This applies especially to big-format enlargers containing a number of lamps for diffused illumination. There an air current is provided by a blower or fan. This is not however built into the lamphouse, since the fan motor would produce vibration during the exposure and hence unsharpness of the enlarged image. Blower motors are therefore invariably separate, with a hose or similar connection to the lamphouse.

ENLARGER LENSES

As we have seen, the optical elements of the modern enlarger are a condenser and the projection lens. Certain conditions are imposed on the design of both.

We have already considered the condenser and its dependence on the negative format. The enlarger lens must equally suit the size of the negative to be enlarged. The focal length of the lens required is here determined by two factors: first, its ability to cover the negative format, and second the range of magnifications obtainable with it. The ideal specifications in each of these respects are directly opposed. So the choice of the best focal length becomes a compromise though not a very difficult one to achieve in practice.

The maximum magnification obtainable for a given height of the lens above the enlarger baseboard is given by:

$$M = \frac{V-F}{F}$$

where V is the distance from the lens to the enlarger baseboard, F the focal length of the lens and M the magnification (ratio of image size to negative size). The shorter the focal length of the lens, the greater therefore the magnification that an enlarger of a given column height can give.

For a given magnification the height of the negative above the baseboard is given by:

$$E = \frac{F(M + 1)^2}{M}$$

where E is the total distance between the negative and the enlarging paper. The shorter the focal length, the more compact can be the enlarger for a given magnification.

(These equations ignore the optical length of the enlarger lens; the practical effect of this in the second equation is that the distance between the negative and the enlarging paper is increased by the constant length of the enlarger lens – a comparatively small factor in practice.)

The relationship between negative-to-baseboard distance and focal length of lens at various magnifications is given in Table IX; this distance plus the height of the lamphouse above the negative is the effective working height of the enlarger. According to the way in which the lamphouse is mounted on the enlarger column, the negative-to-baseboard distance at the maximum degree of enlargement may be equal to or slightly greater than the column height.

The shortest focal length of enlarger lens that can be used with a given negative size is limited by the ability of the lens to cover that format. In camera work wide angle lenses are available to cover large negative sizes with a comparatively short focal length. This coverage is obtained at the expense of certain optical qualities – especially evenness of illumination.

With a wide angle lens the light intensity reaching the edge of the enlarging paper is appreciably lower than the light intensity at the centre of the image plane. This relationship is determined by the laws of optics and not by enlarger lens design. The intensity of illumination falls off very rapidly with increasing image angle; to keep it within acceptable limits the image angle should therefore not exceed about 40–45°. At the higher magnifications (above say 10 times) this corresponds to a focal length approximately equal to or a little longer than the diagonal of the negative format to be covered. So the focal length of the enlarger lens should generally be similar to the focal length of the normal camera lens for that negative size.

In practice enlarger lenses are often chosen with a slightly longer focal length to improve the evenness of

IX – NEGATIVE-TO-BASEBOARD DISTANCES IN ENLARGING

Magnification (Diameters)	*Focal Length of Lens* 50 mm / 2 inches	75 / 3	90 / $3\frac{1}{2}$	105 / $4\frac{1}{8}$	135 / $5\frac{3}{8}$	150 / 6	*mm* / *inches*
1	8	12	14	$16\frac{1}{2}$	$21\frac{1}{4}$	$23\frac{3}{4}$	in.
	20	30	36	42	54	60	cm
2	9	$13\frac{1}{2}$	$15\frac{3}{4}$	$18\frac{1}{2}$	$24\frac{1}{4}$	27	in.
	22·5	33·8	40·5	47·3	60·8	67·5	cm
3	$10\frac{3}{4}$	16	$18\frac{3}{4}$	22	$28\frac{1}{2}$	32	in.
	26·7	40	48	56	72	80	cm
4	$12\frac{1}{2}$	$18\frac{3}{4}$	22	$25\frac{3}{4}$	$33\frac{3}{4}$	$37\frac{1}{2}$	in.
	31·3	46·8	56·2	65·6	85	93·6	cm
5	$14\frac{1}{2}$	$21\frac{3}{4}$	$25\frac{1}{4}$	$29\frac{3}{4}$	39	$43\frac{1}{4}$	in.
	36	54	64·8	75·6	97·5	108	cm
6	$16\frac{1}{2}$	$24\frac{1}{2}$	$28\frac{3}{4}$	$33\frac{3}{4}$	44	49	in.
	40·8	61·3	73·5	85·7	110	123	cm
8	$20\frac{1}{4}$	$30\frac{1}{2}$	$35\frac{1}{2}$	$41\frac{3}{4}$	$54\frac{1}{2}$	$60\frac{3}{4}$	in.
	51	76	91·3	107	137	152	cm
10	$24\frac{1}{4}$	$36\frac{1}{4}$	$42\frac{1}{4}$	50	65	$72\frac{1}{2}$	in.
	60·5	91	109	127	164	182	cm
12	$28\frac{1}{4}$	$42\frac{1}{4}$	$49\frac{1}{4}$	58	76	$84\frac{1}{2}$	in.
	70·5	106	127	148	190	222	cm
15	$34\frac{1}{4}$	$51\frac{1}{4}$	$59\frac{3}{4}$	70	92	103	in.
	85·5	128	153	179	230	256	cm
20	44	66	77	91	—	—	in.
	110	165	198	232	—	—	cm

The above distances are rounded off, and also ignore the optical length of the lens—this may add about 1 inch to the overall distance.

X – FOCAL LENGTHS OF ENLARGER LENSES

Negative Size	*Condenser Diameter* *cm*	*in*	*Focal Length of Lens* *mm*	*in*
8 × 11 to 13 × 17 mm	2·5	1	25	1
18 × 24 to 24 × 36 mm	5–7·5	2–3	50–60	$2–2\frac{1}{2}$
4 × 4 cm ($1\frac{5}{8}$ × $1\frac{5}{8}$ in.)	7·5	3	60	$2\frac{1}{2}$
4·5 × 6 and 6 × 6 cm ($1\frac{5}{8}$ × $2\frac{1}{4}$ and $2\frac{1}{4}$ × $2\frac{1}{4}$ in.)	9–11·5	$3\frac{1}{2}–4\frac{1}{2}$	75–90	$3–3\frac{1}{2}$
6 × 9 cm ($2\frac{1}{4}$ × $3\frac{1}{4}$ in.)	11·5–12·5	$4\frac{1}{2}–5$	100–105	$4–4\frac{1}{4}$
9 × 12 cm and $3\frac{1}{4}$ × $4\frac{1}{4}$ in.	16·5	$6\frac{1}{2}$	135	$5\frac{3}{8}$
4 × 5 in.	18	7	150–165	$6–6\frac{1}{2}$
13 × 18 cm (5 × 7 in.)	23–24	$9–9\frac{1}{2}$	210	$8\frac{1}{4}$
18 × 24 cm and 8 × 10 in.	38	15	300–360	$12–14\frac{1}{4}$

illumination and also to reduce the effect of residual lens aberrations which are usually most pronounced near the edges of the image field. The suitable focal lengths of enlarger lenses for different negative sizes are shown in Table X on page 143.

Longer focal lengths can of course be used (and are used when a large-format enlarger is employed to enlarge smaller negatives), but in this case the maximum degree of enlargement obtainable is reduced as indicated by the equations on page 141 and Table IX on page 143.

The image angle varies also with the degree of enlargement and becomes narrower at lower magnifications, since the lens-to-negative distance then is increased. Hence it is the coverage at high magnifications which matters. This is also the reason why enlargements made with a cheap enlarging lens may show a falling off of definition and a lightening of the picture near the corners at high magnifications, while prints made at lower degrees of enlargement may be adequately illuminated and sharp over their whole area.

LENS QUALITY

The optical quality of an enlargement can only be as good as that of the enlarger lens. The definition of the enlarging lens should therefore be at least as good as that of the camera lens – otherwise the optical quality of the latter is wasted. Hence it pays to obtain the best lens one can possibly afford. Nor is high lens speed important. In fact, enlarger lenses have maximum apertures ranging between $f3 \cdot 5$ and $f5 \cdot 6$. There is no advantage in having a very big maximum aperture since a short exposure time is more cheaply obtained by a stronger lamp.

The demands on quality in enlarging lenses are in fact quite high. In the first place the lens must have a flat field – that is, it should give an evenly sharp image of the negative over the whole surface of the enlarging paper. In cheap camera lenses curvature of the field is sometimes compensated by running the film in a slightly curved film plane; obviously this is not possible with the enlarging paper on the baseboard.

The colour correction of an enlarging lens on the other hand need not be as high as in the case of a camera lens as long as only blue-sensitive bromide papers are used. For

printing colour negatives – and when using variable contrast papers – full colour correction of the enlarging lens is however essential.

The lens must also be free from distortion, especially if the enlargement is used as a basis for accurate measurements of image proportions. A simple check on this point is possible by placing a grid image in the negative carrier and projecting this on the baseboard. Such a grid can consist of fine straight lines, ruled with Indian ink on a piece of clear film (or even on a sheet of tracing paper). The lines are ruled in two directions parallel to the length and width of the negative area (see illustration on page 139). In the projected image these lines should be straight not only in the centre but also near the edges of the field. If the lens suffers from distortion, the lines near the edges of the projected area curve inwards or outwards.

In the middle of the image edges the lines in both directions should also be equally sharp. If they are not, the lens suffers from astigmatism and is not suitable for high-quality enlargements. The sharpness of the line intersections in the corners also shows whether the definition is uniform. If the lines at the edges of the field are sharp at one focus setting and need refocusing to be sharp in the centre, the lens suffers from curvature of field.

Another common lens fault is a movement of the plane of sharpness when the lens is stopped down. Such a focus shift is particularly troublesome in an enlarging lens, since the iris diaphragm is there used extensively to control the image brightness and hence the exposure time.

CAMERA LENSES IN ENLARGERS

On most enlargers the lens is interchangeable to permit a selection of systems of different makes. Frequently the enlargers will also take the interchangeable lenses of certain cameras.

In principle there is one argument against employing camera lenses in enlargers: while the camera lens is corrected for optimum definition at fairly great object distances, enlarging lenses are designed for best image quality at the much closer range corresponding to an enlarger set-up. Camera lenses may under these conditions not give the best results.

In practice this is likely to be a problem only at low degrees of enlargement, below about 7 or 8 diameters. And with good quality lenses of short focus the differences in correction are by no means great, so that expensive lenses of miniature cameras can often be used. In fact, it is frequently the lens settings like the iris diaphragm control which are more adapted to camera use on a camera lens and therefore less convenient to operate when the lens is screwed into the lens panel of an enlarger.

THE IRIS DIAPHRAGM

Enlarging lenses usually have an iris diaphragm to reduce the light going through the lens, for example when dealing with very thin negatives or at low degrees of enlargement. There the brightness of the projected image on the paper might call for very short exposure times which are not easy to time accurately. By stopping down the lens we arrive at more conveniently handled exposures.

On stopping down, an enlarger lens should not change its image quality appreciably. Since the maximum enlarging lens aperture is small when compared with high-speed camera lenses, this maximum aperture is often fairly near to the optimum lens aperture for definition.

The iris diaphragm of an enlarger lens should have provision for comfortable setting in the dark. Modern enlarging lenses have click stops, where the aperture ring (or lever) engages positively at each setting. To set a specific lens opening, it is then only necessary to count the clicks.

Nor is it necessary to know the actual aperture value. The click stops need be marked only with relative exposure time equivalents: 1–2–4–8–16.

This proportional variation of exposure time with lens openings is valid with diffused-light and semi-diffused enlargers. With condenser enlargers using a point source it is valid only if the cone of light from the lamp and condenser fully fills the rear of the enlarging lens. If the light cone is focused on the centre of the lens and does not completely fill it, the first stages of stopping down do not reduce the light proportionally.

The enlarger lens aperture scale can also be illuminated – generally by internal light guides using the light from inside the enlarger. Such illuminated scales must be suitably

shielded to prevent light from reaching the baseboard.

In practice enlargers with point source illumination are arranged to focus the condenser beam at a point beyond the lens to avoid having to refocus the light source for different degrees of enlargement (page 127). The light cone is then larger than the lens and this problem does not arise.

COATED LENSES

Nearly all modern enlarging lenses have their glass surfaces coated with a thin film of metallic fluoride. This reduces the amount of light reflected between the surfaces of the lens elements. Consequently less stray light is scattered over the bromide paper, resulting in more brilliant prints. Coating of the glass surfaces of a lens slightly increases its light transmission. A coated lens can usually be recognised by observing the surface – any reflections in it would have a purplish or yellowish tinge.

Light is reflected at every air-glass interface of the lens. The effect of coating is thus greatest with multi-component compound lenses. Since coating cuts the loss of light from about 5 per cent to less than 1 per cent for each surface, the speed of, for instance, a four-component lens (eight air-glass surfaces) is increased by over one-third. But the reduction of light scatter is more important.

The effect depends on light interference. This is set up by the presence of the thin coating, between the incident and reflected beams at the glass surfaces. For any one wavelength complete removal of all reflections can be achieved under appropriate conditions.

As more or less white light – a mixture of wavelengths – is used in the enlarger, reflections are in practice not completely eliminated. Ideally the coating should have a thickness of about one quarter of the wavelength of light – approximately 100 to 150 millimicrons or 4–6 millionths of an inch. Such thin coatings are produced by evaporating the coating material on to the glass surface in a vacuum. The layer must also have a refractive index intermediate between the refractive indices of the glass and of air. Under these conditions the crests of the light waves reflected from the surface of the coating coincide with the troughs of the waves reflected at the interface between the coating and the glass; the light waves are then out of phase and neutralise each

other so that reflection is decreased or entirely eliminated. The missing radiation reappears in the transmitted beam which has been shown to contain as much as 99·6 per cent of the original or incident radiation.

FOCUSING THE IMAGE

To increase the magnification given by an enlarger the distance between the lens and the enlarging paper has to be increased. On a vertical enlarger the usual method is to raise (or lower) the enlarger head on its column or other support. For each magnification the lens-to-negative distance must be adjusted as well to obtain a sharp image on the baseboard. The focusing movement provides this adjustment of the lens-to-negative distance. Optically the relationship between the distances is given by the equation:

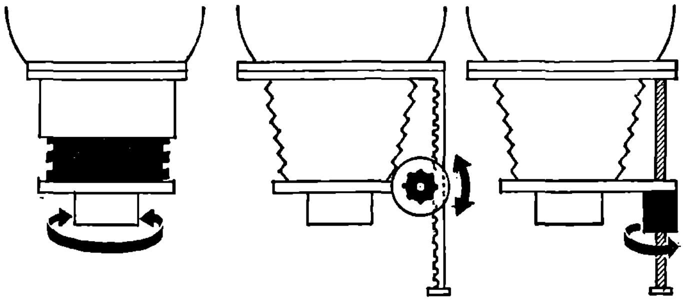
$$u = \frac{vF}{v - F} = \frac{F(M + 1)}{M}$$

where u is the lens-to-negative distance, v the lens-to-baseboard distance, F the focal length of the lens and M the degree of magnification. (This ignores the optical length of the lens).

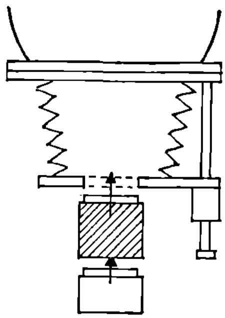
The lower the degree of magnification, the larger becomes the value of the expression $(M + 1)/M$, and hence the greater the lens-to-negative distance. For same-size projection the lens-to-negative distance is twice the focal length, and grows rapidly for reductions. At high magnifications the lens-to-film distance approaches, but cannot become shorter than, the focal length.

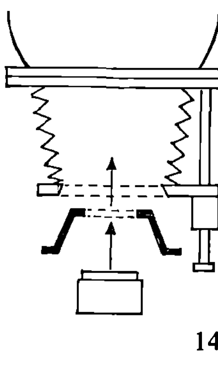
It is easy enough to arrange for the focusing movement to provide a minimum lens-to-negative distance equivalent to the focal length of the lens. So the maximum magnification of an enlarger is not limited by the focusing movement – only by the height to which the enlarger can be raised above the enlarging paper on which the image is projected. Normally, with a vertical enlarger, this is determined by the height of the enlarger column, but lens-to-paper distances can be extended by other means for really big enlargements (page 164).

The lowest magnification is however determined by the extent to which the lens can be moved away from the nega-



In simple enlargers the lens often screws in and out of a helical tube for focusing (*left*). Bellows enlargers may have a rack-and-pinion movement (*centre*) or a friction drive. Alternatively the lens panel may be raised or lowered with a micrometer screw (*right*).





To extend the maximum negative-lens distance for low magnifications or even reductions, an extension tube may be used (*upper right*).

Where the minimum negative-lens distance is too great, for instance when using a specially short-focus lens for enlarging ultra-miniature negatives, a recessed lens panel or adapter can bring the lens nearer to the negative plane.

tive. To avoid too bulky a focusing movement, many amateur enlargers, especially those taking negative sizes up to 6 × 9 cm or $2\frac{1}{4} \times 3\frac{1}{4}$ inches, have a minimum magnification limit of 2 to 3 diameters. The argument is there that few photographers would want enlargements of lower magnification than this; if a negative is to be enlarged, it is worth enlarging to at least twice its original size. For lower magnifications the lens can often be fitted to the enlarger with an extension tube which then gives the extra lens-to-negative distance required – even for same-size copying.

This limitation does not apply to miniature enlargers on the one hand (though there low magnifications are even less necessary) nor to larger-size professional instruments on the other. In the first case the focusing travel required with a shorter focus enlarging lens is much less, so that providing an extensive focusing range causes no difficulties. (And if a shorter-focus lens is used on a medium format enlarger to cope with miniature negatives, the focusing travel available is more than required anyway.)

In the second case, with large-format professional enlargers low magnifications are essential: for instance a 13 × 18 cm or 5 × 7 inch enlargement from a 10 × 12·7 cm or 4 × 5 inch negative needs a magnification of only 1·4 times at the most. Professional enlargers therefore must have this extended focusing provision.

THE FOCUSING MOVEMENT

While the lens-to-negative distance is adjusted, no light must of course escape between the illuminated negative and the lens. As in a camera, this part of the optical system is therefore enclosed more or less light-tight.

The mechanical lens adjustment may be provided either by a helical focusing mount (screwing the whole lens in and out) or by a bellows movement.

Helical mounts are common in low-priced enlargers and usually consist of two metal tubes sliding one inside the other, guided by a coarse spiral thread. Rotation of the front tube (carrying the lens) at the same time pushes it farther out or in. The tubes may also slide inside each other without a thread, being moved by a knob via a friction drive or a rack-and-pinion system.

Bellows are a much more versatile way of connecting the enlarging lens with the lamphouse, but are also more elaborate (and hence more expensive) in construction. Here the lens panel has to travel along a rail or pair of rails, being again moved by a knob through a friction drive or a rack-and-pinion arrangement.

FINE FOCUSING

The straightforward way of focusing the enlarger is to observe the image projected on a sheet of white paper on the baseboard or the paper holder. Once the approximate magnification required is obtained by raising or lowering the enlarger head, turn the focusing control gradually while watching the image become progressively more distinct until the point of maximum sharpness. This point is not very easy to appreciate until it has been passed, i.e. the image becomes less sharp again. The manipulation of focusing therefore usually involves going to and fro, past the sharpest point, by trial and error and reducing the amount of adjustment with each successive stage. This is the technique of "bracketing".

To facilitate the fine adjustments during focusing, some enlargers have an additional fine focusing movement. This may be a supplementary helical mount for the lens to enable it to be turned in and out by small amounts, or a micrometer screw system for moving the bellows.

The sharpness of the projected image is most easily observable if the lens is fully open at maximum aperture for focusing. The depth of focus (the adjustment tolerance for sharpness – analogous to the depth of field – page 40) is then least so that the definition of the picture changes most rapidly. If however the lens suffers from focus shift on stopping down (page 146) it is better to focus at the aperture to be used for the exposure.

The rate at which the visual sharpness changes during focusing is greatest at high magnification and very much less at low ones. Here accurate focusing can become tricky since the sharpness appears to change only little with considerable movement of the lens. Partly this is again due to increased depth of focus, but partly also to the fact that the focusing movement alters both the lens-to-negative distance and the lens-to-paper distance simultaneously and in opposite

senses. These changes tend to compensate each other (they do so fully at same-size projection). The change in visual image sharpness would be greater if it were possible to adjust only one of the distances (lens-to-negative *or* lens-to-paper) during focusing. In an enlarger this is however rarely practical, since it would involve moving either the whole of the comparatively heavy lamphouse or the enlarger easel. The mechanical precision required for such movement is attainable only with expensive optical set-ups – so this type of movement is mostly used in large horizontal enlargers or process cameras for graphic arts use.

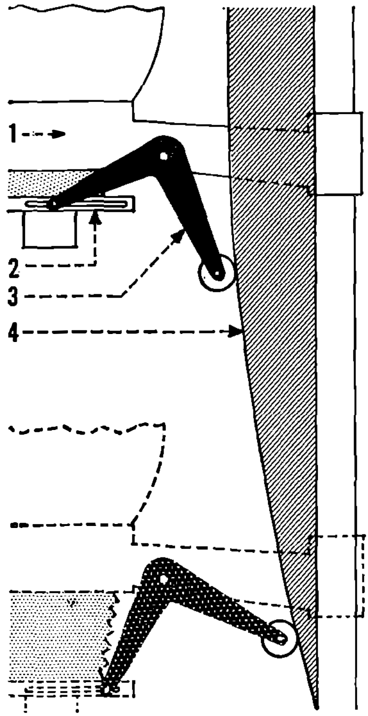
AUTOMATIC FOCUSING

From the equations on page 148 it is evident that for a given lens the distances from the lens to the negative and to the enlarging paper respectively are strictly dependent on each other if a sharp image is to be obtained. In other words, whenever the lens-to-paper distance is increased or decreased (for higher or lower magnifications), the lens-to-negative distance must be decreased or increased accordingly.

It is possible to gear the movement of the enlarger head on its column with the focusing movement in such a way that the lens-to-negative distance is automatically readjusted to yield a sharp image as the magnification is changed.

This is the principle of the automatic focusing enlarger. It greatly speeds up the production of prints of different magnifications from different negatives. It also makes it far easier to obtain an enlargement of a strictly specified magnification – without a series of alternate trial and error adjustments of the enlarger height and the focus. (For refocusing the negative after moving the enlarger head on the column also changes the scale of the image.)

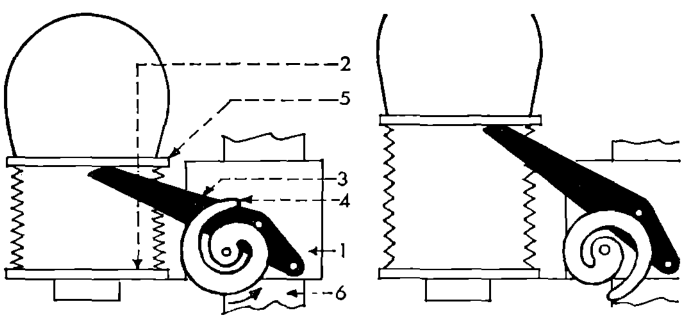
The linkage between the enlarger head and the focusing movement is usually a pivoted lever, one end of which is connected to the lens tube or panel, while the other rides on a suitably shaped cam. The latter may either be attached to the enlarger column or – in the case of a parallelogram movement (page 171) – fixed inside the parallelogram system itself. Alternatively, the cam may move the negative carrier (possibly together with the whole upper part of the lamphouse). Here it is the cam which moves (page 153), the movement being controlled by the travel of the enlarger



In the automatic focusing enlarger the lens panel is moved by a lever riding on a precisely shaped cam. As the lamphouse moves up on the column, the lens is also raised (*upper right*); at lower magnifications the cam system extends the lens (*lower right*). With a cam of the correct shape to match the focal length, the image remains sharp all the time.

1, lamphouse support; 2, lens panel; 3, focusing lever and roller; 4, focusing cam.

There are many constructional variants of this system.



One alternative is a helical cam 4, geared with the movement of the lamphouse support 1 on the column 6. The focusing lever 3 rides on this cam and raises or lowers the negative carrier 5 together with the upper half of the lamphouse. The cam may be interchangeable for different lenses.

head up and down on the column. The shape of the cam is based on a curve of the equation similar to:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{F} \text{ or } F^2 = (u - F) \times (v - F)$$

from which the equation on page 148 is derived.

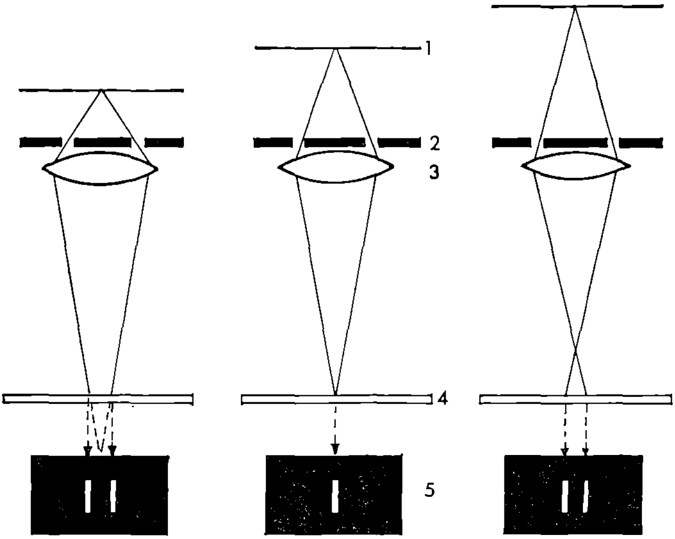
Since the focal length of the enlarging lens is one of the parameters of this curve, the cam must be matched to the exact focal length of the lens used. Hence a change of enlarging lens – even if of nominally the same focal length – will upset the automatic focusing accuracy. (In lens manufacture a tolerance in the exact focal length of plus or minus 4 per cent of the nominal focal length is accepted as permissible.) Usually the focusing cam is precisely adjusted before an automatic enlarger leaves the factory; this adjustment must not be tampered with.

The focusing movement is also set to the precise image plane on the enlarger baseboard. If a masking frame is used, some compensation for its thickness may be necessary. Some automatic enlargers have provision for raising the whole head, including the focusing cam, to compensate for masking frames of different specified thicknesses.

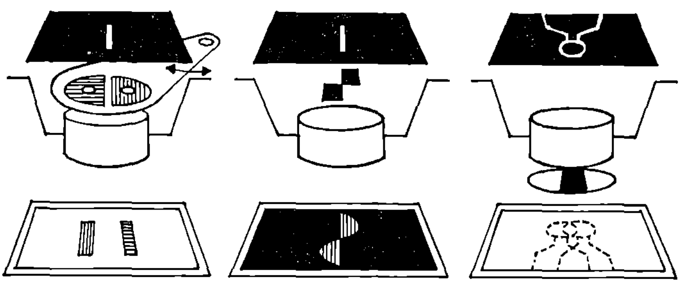
The main weakness of an automatic focusing enlarger, especially of cheaper models, is the inaccuracy introduced by wear on the focusing cam or in the mechanical linkages. So if any looseness has developed in use, it may be advisable to have the focusing movement reset from time to time. This is especially necessary with professional enlargers which are in constant use. The higher the precision of the enlarger, the lower of course the risk of it going out of adjustment.

SEMI-AUTOMATIC FOCUSING

A few enlargers indicate the correct setting of the lens for maximum sharpness by a pair of scales on the column or other support and on the focusing movement. The scales may be graduated in magnifications, and when the column scale and the lens scale are set to the same figure the image is approximately sharp. In practice this is of more use to obtain specific degrees of magnification rather than sharp focus, since the exact setting still has to be ascertained by observation of the image.



Split-beam focusing indicators depend on isolating two ray bundles from opposite zones of the lens and checking their coincidence. In this set-up, rays from a slit image 1 isolated by an aperture plate 2 before the lens 3 come to a sharp focus in the image plane (baseboard) 4 when the lens is correctly focused (*centre*). The image then appears as a single slit 5. If the lens setting is incorrect, the rays converge to a point either behind the image plane (*left*) or in front (*right*) and two slits are visible.



In practical versions of this system the negative carrier can be moved so that a built-in slit is brought into the optical path; at the same time a twin-aperture mask swings behind the lens (*left*). The mask openings may carry red and green filters to yield coloured double slit images. Alternatively, two screens below the negative carrier may shield off half the image of a slot from each half of the lens. When out of focus, the two halves of the line spread sideways in opposite directions (*centre*).

An improvised method (*right*) requires only an opaque strip across the lens centre. Two images are then formed on the baseboard.

Simplified cam-driven focusing systems are sometimes used on inexpensive amateur enlargers to focus roughly and to show the image at the required scale of reproduction, but saving the cost of precision cams. The final fine focusing adjustment is here again done by hand.

Numerous amateur enlargers also use optical focusing aids similar in effect to a split-field rangefinder. These are based on forming two separate images with two opposite sides of the enlarging lens (page 155). If the lens is incorrectly focused, the two lens sections form a double but comparatively sharp image instead of a single blurred one. At the point of maximum sharpness these double images fuse into a sharp single one – which is easy to assess visually.

Such split-image rangefinding devices may consist of a twin-aperture mask swung into the optical path so that the apertures pass just two bundles of light rays near opposite edges of the lens. At the same time the negative carrier is replaced by an opaque screen with a fine clear line or slit, located in exactly the plane of the negative. (This may be part of the negative carrier.) The two clear parts of the lens then project two images of the line or slit which coincide on the baseboard when the lens is accurately focused, but appear as two line images when the focus is not correct. For further differentiation, the mask apertures may carry a red and a green filter respectively.

Alternatively, two little masks may move into the light path just in front of the slit or line in the negative carrier, located so as to screen one half of the line from each side of the enlarger lens. When the lens is not correctly focused, the images of the line become blurred and the two halves spread out in opposite directions, fusing into one single sharp line of even thickness at the correct focus setting.

A simple device for split-image focusing can be improvised by placing a piece of opaque material (about one-third in width of the diameter of the enlarging lens) across the front of the lens. The image then appears divided when out of focus, and in register when in focus. It helps to have a small test object in the negative carrier, e.g. a fine line scratched in the emulsion of a heavily over-exposed and developed waste negative. The opaque strip in front of the lens can be fixed on a cap or similar device, for easy removal for the actual exposure.

If the split image effect is not very distinctive, the position of the lens attachment may need adjustment until two separate images are visible when the lens is not sharply focused.

THE NEGATIVE CARRIER

The purpose of the negative carrier is to hold the negative flat and parallel to the lens plane between the lens and the lighting system. For easy changing of the negative the carrier slides into a slot in the enlarger body from the front (or from above in horizontal enlargers).

In its simplest form, for plate negatives, the carrier needs to be little more than a frame which holds the plate in a shallow rebate around the inside of the image aperture. The plate may be held in position by spring clips – necessary for horizontal enlargers.

To keep film negatives flat, the classical way is to sandwich them between two sheets of glass. These may be supported in a frame or hinged together to open like a book. Negative carriers for bigger sizes sometimes support the glass plates themselves in a rotating frame within a larger holder. This permits rotation of the negative – e.g. by a knob outside the carrier – to help in squaring up the image with the sides of the paper holder. This feature is useful in enlargers taking the paper in roll cassettes (page 259) which are not easily moved or turned about on the enlarger easel.

The carrier must also contain a mask which shields off all light from outside the image area of the negative. Such light, coming through the clear edges of the negative, is otherwise liable to be scattered all over the printing paper surface and to degrade the image. In practice the mask is slightly smaller (by about 1–2 mm) than the actual negative format. It may be made of black plastic, paper or even very thin sheet metal. Red transparent plastic masks may also be used and have the advantage that negative numbers at the edge of a roll of 35 mm film are still visible for identification on the enlarger baseboard. A sandwiching type of negative carrier will take negatives of all sizes up to the maximum for which it is designed, simply by fitting alternative masks.

Changing masks and indeed positioning the film accurately on the mask is somewhat cumbersome (especially if the film

curls). So a few enlargers have adjustable masking strips built into the carrier or below the negative stage. Movement of these strips – a little similar to the masking strips of a masking frame (page 255) – effectively screens off all light from around the negative once the latter is in the carrier. This is quickly done while observing the projected image on the baseboard, and is by far the most convenient way.

The negative carrier, or (more usually) the enlarger head itself just below the negative stage, often has wings or trays at the side. These hold overhanging film lengths when roll or miniature films are inserted in the enlarger in long lengths.

NEGATIVES IN STRIPS

While some photographers prefer to store their negatives – especially of 35 mm miniature films – in complete lengths of up to 36 exposures, this is not necessarily advisable. Finding a given negative here involves handling the complete roll, and – more important – unrolling and re-rolling a length of film. In the course of this the risk of mechanical damage (scratches etc.) to the film is considerable. The film trays do not reduce this risk; they merely prevent the film lengths from getting in the way.

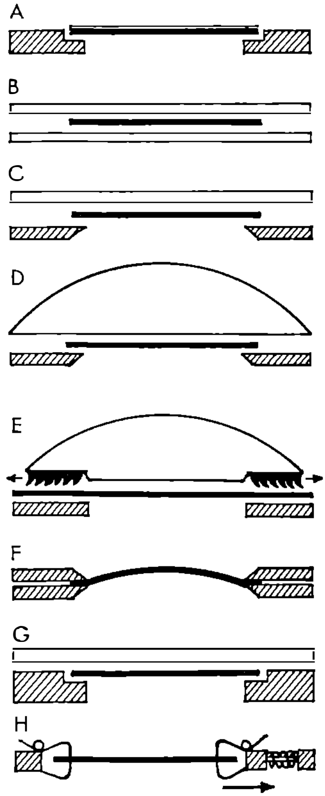
On the other hand handling and inserting single small-format film negatives into a carrier is cumbersome. It is also liable to lead to fingerprints on the negative, unless the film is handled extremely carefully. A good compromise is therefore to store the film in strips of 4–6 negatives (for 35 mm film) or 3–4 images (roll film sizes). Such strips are easily kept flat in suitable envelopes, are convenient to handle and the extra film to one or both sides of the negative actually being printed provides additional support to keep the film flat in a glassless carrier (below).

When moving a film strip from one negative to the next, the film should not be under pressure in the carrier as otherwise scratches are likely to arise. Some enlargers have provision for raising the top glass or frame of the negative carrier during film transport.

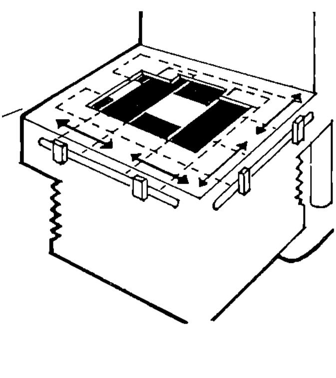
GLASSLESS CARRIERS

The double glass carrier is certainly the most effective way of keeping a film negative really flat. It is also the most effective way of attracting dust and sandwiching it between

NEGATIVE CARRIERS



For plates, the negative carrier in an enlarger need consist only of a rebated frame (A). The most usual way with films is to sandwich them between two glass plates (B) or between one plate and an open frame (C). In some enlargers the condenser presses the film against the negative carrier aperture (D). More sophisticated versions of this arrangement (E) use an elastic grooved ring – surrounding the frame aperture of the condenser – to press down on the sides of the film to tension the latter. This also keeps the condenser out of direct contact with the film itself. Glassless carriers may grip the films between two frames (F) or hold it in a channel between a grooved carrier and a top plate with a cut out mask (G). With these glassless carriers the negative may not always lie fully flat. Large-size glassless sheet film carriers therefore both grip and tension the film by spring loaded cheeks (H).



Some enlargers have movable masking strips built into the unit just below the negative stage. These strips permit masking down of the negative to the size of the image area to be enlarged – thus reducing stray light as far as possible.

the negative and the glass. The enlargements later on then require extensive spotting (page 446). Glass negative carriers therefore need thorough and frequent cleaning, and negatives should be dusted individually before insertion.

Even this is not always effective, for firm polishing of the glass surface charges it electrostatically, so attracting more dust. Anti-static dusting brushes (incorporating a piece of weakly radio-active material to help discharging the electrostatic charge built up) reduce this trouble but do not completely eliminate it. In constant use the glasses of a negative carrier also begin to collect tiny scratches which show up in the enlargement.

Enlargers for formats up to 6 × 6 cm or $2\frac{1}{4} \times 2\frac{1}{4}$ inches therefore frequently use glassless carriers. Here the film is sandwiched between two metal or plastic frames which at the same time act as the negative mask and hold the film by the edges only. The number of dust catching surfaces is thus reduced to two, and negatives are easy to clean quickly before insertion in the enlarger.

Glassless carriers are particularly effective with 35 mm. films since there the carrier can support the perforated film edge for holding the film flat. The film itself is usually in a channel similar to the film track on modern miniature cameras. With films in strip form the negatives to either side of the one being enlarged are also held by the carrier and help to keep the film frame in the aperture flat.

With formats up to 6 × 6 cm or $2\frac{1}{4} \times 2\frac{1}{4}$ inches the film edge may be gripped by the glassless carrier is rather narrower and the film itself is more likely to curve, especially if the negative stage gets warm. This buckling is again minimized if the film is used in strips of three or four negatives rather than single ones. The depth of focus of the enlarger lens usually covers very slight deviations of the film from flatness.

With larger formats the unsupported area of film in a glassless carrier becomes too great to keep the film reasonably flat. Thick sheet film supports (0·2 mm) might still be all right up to 6 × 9 cm ($2\frac{1}{4} \times 3\frac{1}{4}$ inches) in size. Large-size glassless carriers however exist which grip the film in spring loaded jaws along two edges and so hold it flat by tension. The carrier has to be fairly large to accommodate this feature.

HALF-GLASS CARRIERS

A compromise between the glass sandwich type and the glassless negative carrier consists of a metal frame to support the film and a single sheet of glass on top to hold it flat. Provided the glass sheet is in contact with the support side of the film, it effectively counteracts curling and is virtually as efficient as a double glass carrier, at any rate with smaller negative sizes. The single glass sheet attracts less dust than two glasses, but still more than a glassless carrier. Also the film must be located accurately on the supporting frame to stay flat.

A variant of the half-glass carrier, popular in 35 mm enlargers, uses the condenser lens of the enlarger to keep the film flat. The negative carrier in this case is again a plastic or metal stage with a shallow channel for the film. The condenser lens is lowered down on to the back of the film and thus acts in the same way as the pressure plate in the camera. When the film is to be moved in its channel, the condenser lens can be raised by a simple lever action.

The bottom surface can still collect dust, but as the condenser stays in the enlarger and is not handled during insertion and removal of the negative strip, this is not serious. Any dust on the upper condenser surface is far enough away from the negative not to show up. This type of carrier is however suitable for strips of film only, and not for single negatives.

NEWTON'S RINGS

Glass negative carriers can sometimes give rise to an irritating phenomenon: the appearance of faint parallel light and dark bands or rings on the print. These are interference fringes produced by the reflection of light between a film surface and a glass surface which are in nearly but not quite perfect contact. If the separation between the two at any point is of the order of the wavelength of light, the light waves reflected between the surfaces may interfere with the light transmitted through them. This is the analogous to the elimination of reflections by lens coating (page 147) but in this case leads to interference fringes which are known as Newton's rings after their discoverer.

No such interference fringes arise if there is either no contact or perfect optical contact between the surfaces. The

rings can therefore be eliminated by separating the back of the negative from the glass by inserting a paper mask.

Alternatively, sandwiching the film with a layer of glycerine between the glasses also gets rid of Newton's rings. This is however a somewhat inconvenient method, though the glycerine does not harm the film.

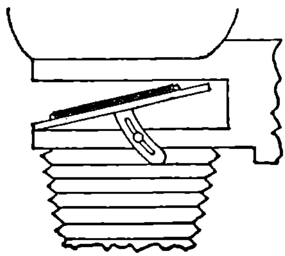
Where the condenser lens is used to hold the film flat, an elastic grooved ring with the fins pointing outwards is sometimes employed to contact the film surface. This keeps an air space between the condenser face and the film (E, page 159) and the fins tend to pull the film outwards to tension it all round the film aperture.

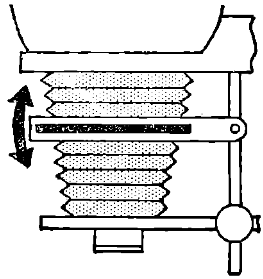
A modern method of eliminating interference fringes is to slightly etch the glass surfaces involved (negative carrier glasses, the underside of the condenser where in contact with the negative etc.). This makes the surface sufficiently irregular to break up interference patterns to microscopic dimensions where they are no longer resolved in the image on the paper. The etching pattern, which is less prominent than the structure of a ground glass screen, does not normally appear in the enlargement, nor does it noticeably affect definition provided the enlarger uses diffused or semi-diffused lighting. Anti-Newton treated glasses are not however recommended in a condenser enlarger with point-source lighting.

TILTING CARRIERS FOR DISTORTION CONTROL

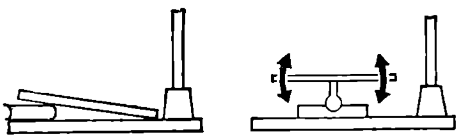
Normally the negative carrier should hold the film parallel with the plane of the lens and the printing paper surface. If these planes are not parallel, the proportions of the image are distorted in the print. This can be used to modify image proportions deliberately, for instance for rectifying converging verticals in a picture of a building taken with the camera not truly level. Some correction is already possible by merely inclining the paper surface on the baseboard; for more extensive image control the negative plane needs to be tilted as well.

For this purpose advanced enlargers incorporate or have provision for fitting a special negative carrier which can be inclined in one or two directions. The carrier may be either



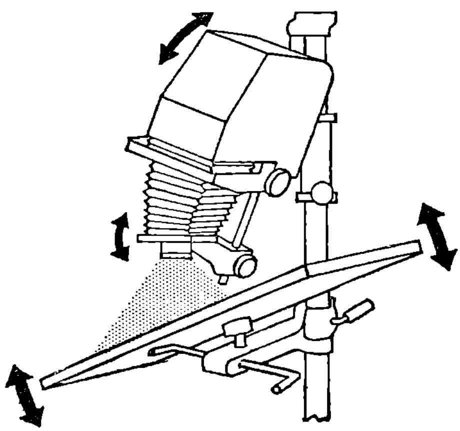


A simple way of tilting the negative carrier (*left*) is to hinge it in a sufficiently large space between the lamphouse and the bellows. More elaborate systems (*right*) may have the carrier within the bellows system itself and hinged at one end.



Baseboard tilts are simplest by placing a book under one side of the paper holder (*left*). Sometimes a supplementary easel can be tilted in a ball and socket joint (*right*).

Advanced professional enlargers may have more elaborate tilting provisions, involving a tilt of the whole lamphouse on the column, a tilting lens panel and a tilting baseboard. With this arrangement the image may however be projected very near to the edge of the easel. A horizontal displacement of the lens (to the right in this case) would recentre the image on the easel, but in turn can lead to uneven image illumination as the lens is no longer centred in the light beam.



pivoted on a supplementary stage or mounted in a bellows arrangement to permit more extensive tilts.

Since such a tilting carrier occupies more space than the slot for the normal negative carrier in an enlarger, the enlarger itself must be specially designed for such tilting.

The technique of distortion control is covered in more detail on page 401.

THE ENLARGER SUPPORT

In a vertical enlarger the lamphouse and optical assembly moves up and down on a support. In its simplest form this is a tubular column mounted on a wooden or metal baseboard. The column itself may be 30 to 60 mm ($1\frac{1}{8}$ to $2\frac{7}{8}$ inches) in diameter and – on miniature to medium format roll film enlargers – 60 to 120 cm or 2 to 4 feet high.

Single columns higher than 4 feet are rare, because the problems of steadiness become serious and enlargers requiring greater negative to paper distances use square, rectangular or girder section columns or more complex support structures (page 167).

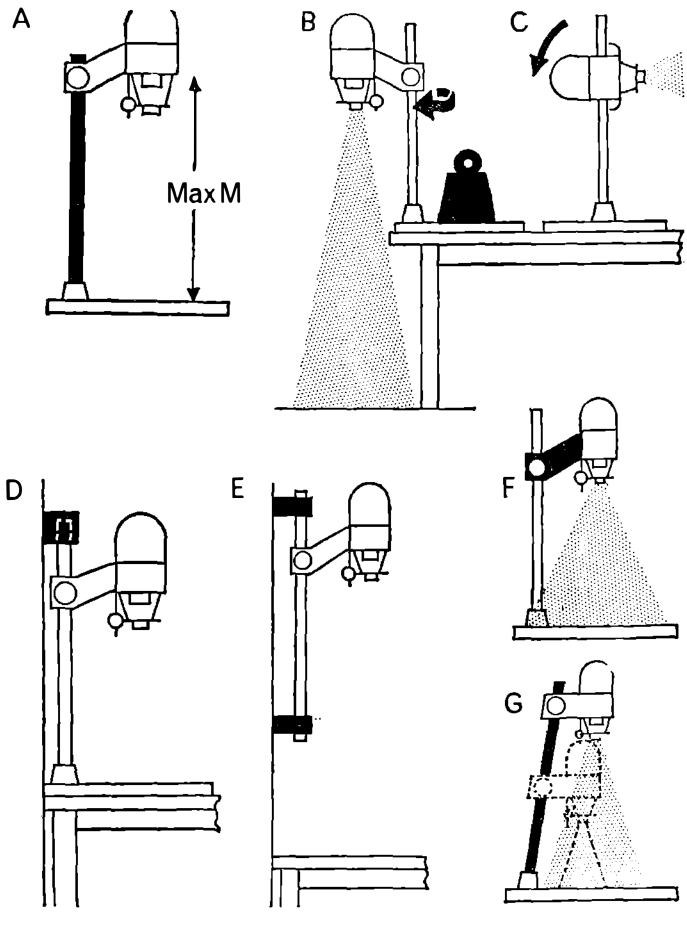
The height of the column determines the maximum magnification obtainable with a lens of given focal length (see Table IX on page 143). With automatic focusing enlargers the automatic setting range does not normally extend to the maximum; a typical range with a 50–60 mm lens (for negatives up to 24 × 36 mm) might be 2–10 diameters. The higher magnifications beyond this limit then require manual focusing of the enlarger lens.

Still greater enlargements are generally possible by setting up the enlarger with its column next to the edge of the working table and swinging the enlarger head round on its column so as to project past the edge of the table on to the floor. (With certain types of enlarger head movement the whole column has to be swung round.) This arrangement adds the height of the working table to the height of the column to increase the effective negative to paper distance for big enlargements.

Since the weight of the enlarger head is no longer above the baseboard, the latter has to be weighted or clamped down to prevent overbalancing.

An alternative way of increasing the magnification range is available if the enlarger head can tilt or swivel on its

ENLARGER COLUMNS



Normally the column height (A) determines the maximum magnification available. Still greater enlargements are however often possible either by swinging the lamphouse round on its column (B) – with appropriate weighting of the baseboard – or by turning the lamphouse horizontal (C) and projecting on a wall or vertical easel.

High columns permit greater magnifications, but are more liable to vibrate. A remedy is to anchor the column top to the wall (D) or use a completely wall-mounted column (E).

At high magnification the column may obstruct the projected beam (F) unless the supporting arm is excessively long. An inclined column (G) keeps the projected beam away from the column base more effectively.

support. The head is there simply turned to project the image horizontally on to a suitable wall or upright easel – it becomes a horizontal enlarger. Before turning an enlarger sideways it is however wise to check that the lamphouse and internal parts of the illuminating system are securely fixed. On many vertical enlargers, condensers and other items may be held in place by their weight only and drop out or fall apart if the head is turned horizontal. In this position the ventilation conditions of the lamphouse are also changed, so it is advisable to check that the enlarger does not get too hot (especially as high magnifications call for long enlarging exposures).

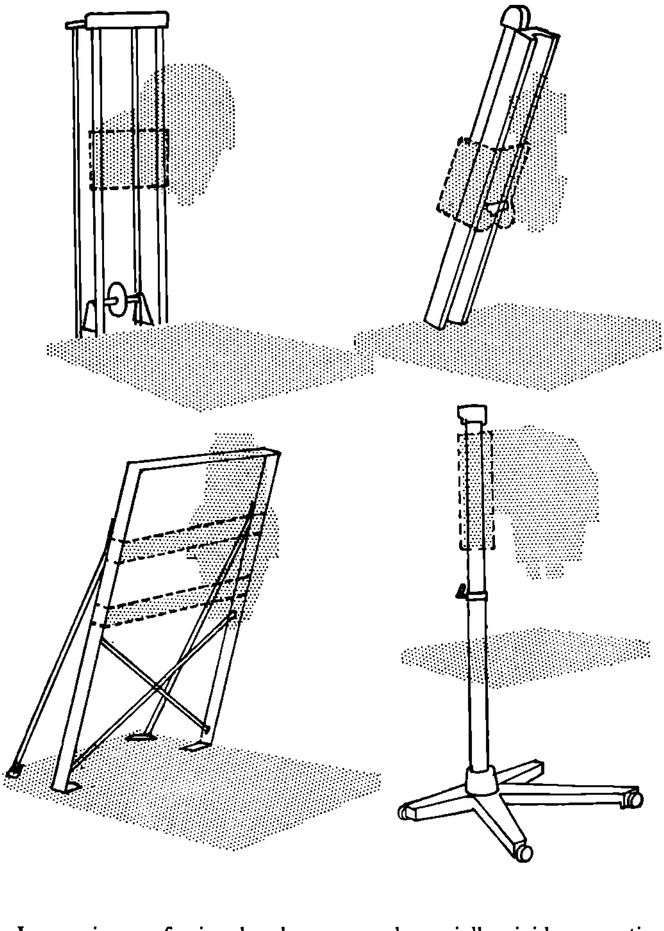
THE PROBLEM OF RIGIDITY

A column supported only at its base and carrying the heavy enlarger head at the top is not a particularly rigid engineering structure. It is very susceptible to vibration – not only every time we touch the enlarger head to adjust the focus, change negatives etc., but also whenever anybody walks about in the darkroom. Any vibration during the enlarging exposure inevitably leads to blurred prints, in the same way as camera shake causes unsharp negatives.

There are various ways of steadying the enlarger set-up. The simplest is to anchor the top of the column to a wall with a suitable bracket. Better still, the whole enlarger may be mounted on a wall using a separate column of the appropriate diameter to take the enlarger head. If possible, select a solid external wall of the building rather than an internal partition wall. The column can in this case be very much longer to enable the enlarger to be raised almost to the ceiling for high magnifications. (Swinging the head round on the column for projection on the floor obviously becomes impossible here.)

The lower end of the column need not go down as far as the baseboard; in fact if the bottom end is mounted some distance above the baseboard it is less likely to intrude into the projected image at higher magnifications and permits the baseboard to be pushed right against the wall. With such a set-up the easel can be the top of a flat working table surface placed underneath the enlarger. If this table is also carefully levelled and then bolted against the wall, parallel alignment of the main optical planes of the enlarger (assuming equally

HEAVY DUTY COLUMNS



Large size professional enlargers need specially rigid supporting columns. A variety of systems is used, some of which are shown here. Multiple columns (*top left*) gain rigidity by supporting each other. Often the enlarger head is counterweighted. Girder columns (*top right*) use a particularly massive girder of suitable profile, and great mass compared with the enlarger head it has to carry. The triangular truss (*bottom left*) is an extensively cross-braced frame on which the enlarger head moves up and down. Floor columns (*bottom right*) are specially solid and stand on their own feet, with both the enlarger head and the baseboard being adjustable. The floor column may also be fixed to the ceiling.

careful levelling when the column is mounted on the wall) is assured. A number of professional enlargers are in fact designed for wall mounting.

With a vertical column the connecting arm or other fixture carrying the lamphouse must be long enough so, that the projected image area clears the bottom of the column even at the maximum magnification. This again makes the structure less stable and some enlargers use an inclined column to improve rigidity. The lamphouse mounting can in this case be quite short, for the enlarger head simply moves out farther towards the centre of the baseboard as the magnification is increased (page 167). For projection over the edge of the table on to the floor the whole column must swing round on the baseboard. The latter would need heavier weighting down in this case.

HEAVY DUTY COLUMN SYSTEMS

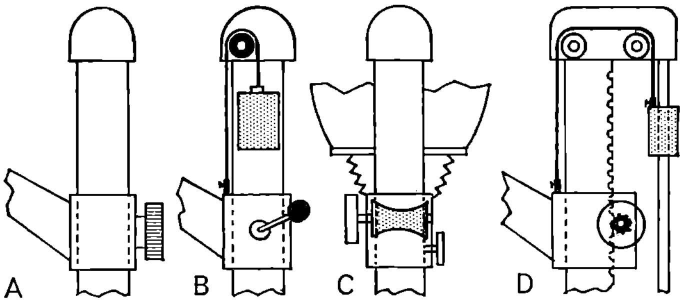
To make the enlarger support more rigid, professional models use double, triple or multiple columns, often with cross bracing and additional lateral bracing to the baseboard. The column in such an arrangement may be upright or inclined, and may also become comparatively massive. A massive column arrangement is obviously superior to a single plain column, and often accommodates also profile cams for automatic focusing and counterweights and other gear associated with the raising and lowering movement of the enlarger head. Such a column is not however the same as a braced support, and the latter is the more rigid arrangement for a free-standing enlarger.

A further variation of enlarger support design employs a floor-supported column of sufficiently solid dimensions to virtually eliminate vibration. This column may in addition be anchored to the wall or ceiling of the darkroom. This arrangement is fairly widely used in big format professional enlargers. The floor support has the further advantage that often the baseboard as well as the enlarger head can be raised or lowered to utilise the maximum working height.

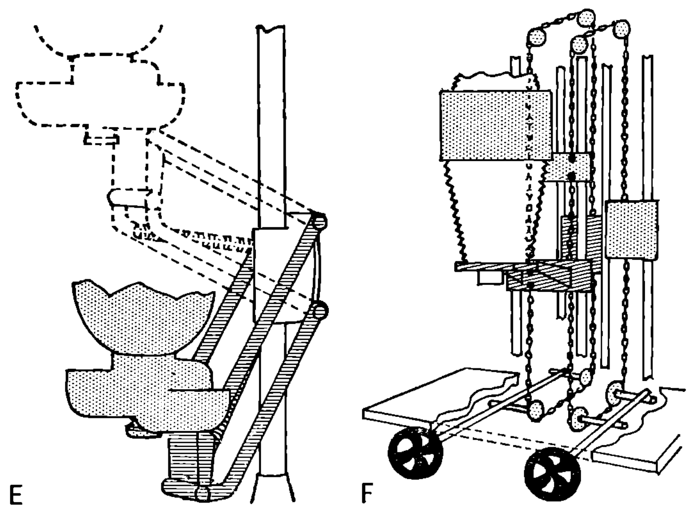
MOVING THE HEAD

The most primitive height adjustment, still used on the majority of popular enlargers, consists of a split sleeve which slides up and down on the column and is clamped into

ENLARGER HEAD MOVEMENTS



On simple enlargers a carrying arm slides up and down the column (A) being clamped in position by a suitable knob or lever. Where the enlarger head is heavy, the column may have a counterweight inside it (B). On some enlargers a friction drive (C) pushes the supporting arm up and down the column; heavy duty versions often use a rack and pinion movement, again with a counterweight (D) which may run along a separate column.



The parallelogram movement (E) with balancing springs permits rapid adjustment. Big format enlargers may have chain drives (F) for the lamphouse and the lens panel, sometimes controlled by hand wheels (or even motors) from the front of the easel.

position by a knob or lever. This sleeve is part of the enlarger arm which carries the head assembly. Raising and lowering the head therefore involves unlocking the sleeve, sliding it to the position required and clamping tight again.

For smooth continuous adjustment the carrying arm may be moved up and down on the column either by a friction drive or with a rack-and-pinion system. Both these are controlled usually with a knob on the sleeve itself, supplemented sometimes by a clamping system to hold the head firmly in the set position.

The awkward part of all these designs is the need for firmly locking the head in position to prevent it from slipping down. Bigger professional enlargers therefore often employ a counter-weighted head. This is linked by a cable or chain to a weight sliding up or down inside the column or along separate rails of a multi-column support. Alternatively, the cable may be linked to a more or less constant-tension spring system acting as counterweighting. In both cases the height adjustment becomes far easier, and any locking system only has to hold the enlarger head against accidental displacement and not against its own weight.

REMOTE CONTROL

With big enlargers reaching over to the column to turn a knob becomes inconvenient. With a counterweighted chain or similar drive it is handier to control the movement of the head from the front of the enlarger. Large-scale professional models sometimes carry a hand wheel underneath the baseboard for smooth and rapid height adjustment.

If the lens panel of the enlarger also runs up and down the same columns, a second hand wheel or knob on the front permits remote focusing in the same way. This is indispensable with big format enlargers when the lamphouse is near the top of its column. Otherwise the operator has to stretch up high to adjust the image sharpness, while still observing the projected image close to the baseboard.

A more advanced scheme of remote control uses electric motors to raise and lower the enlarging head, and sometimes also for the focusing movement. A motorised enlarger obviously increases both working speed and convenience; two simple switches are enough to control the up and down

movement of the enlarger head together with the lens unit.

Such motors are built into a few professional enlargers. Separate motors are also available for certain models for attachment to the head adjustment and the focusing movement respectively.

Elevation and focusing motors must of course be reversible to effect their adjustment in both directions. Microswitches generally cut out the motor at the end of the travel of the movement concerned. The focusing motor should ideally provide two-speed operation for coarse and fine focusing.

PARALLELOGRAM SYSTEMS

Instead of raising the enlarger head on a fixed arm, some enlargers use a set of four swinging arms, two on each side. At one end the arms are pivoted to a clamping sleeve fixed to the enlarger column, and on the other end they are attached to the lamphouse carrier itself. The four pivoting points at each side form a parallelogram – hence the description of the system – which ensures that the optical axis of the enlarger system remains correctly aligned during raising and lowering.

The big advantage of the parallelogram support is the ease of moving the enlarger head. A strong spring within the parallelogram counterbalances the weight of the head assembly, so that the latter stays put at any height above the baseboard. The drawback is a slightly lower lateral stability and the fact the enlarger setting is easily disturbed when inserting or removing the negative carrier to change negatives. While the parallelogram guides can be clamped in position, this is rarely absolutely firm.

A parallelogram movement can still incorporate an automatic focusing cam, which in this case is attached to the parallelogram system itself. For automatic focusing the supporting sleeve which carries the whole assembly must of course be in a fixed position on the enlarger column, usually determined by a locating pin. Several locating positions may be provided – for example with intermediate collars – to allow for paper holders or masking frames of different thickness.

In addition to the swinging movement of the parallelogram arms, the sliding movement of the whole sleeve is still

available to complement the magnification range. With the sleeve at the top of the column, the full upward swing of the arms gives extra magnification.

WIRING AND SWITCHING

With a tungsten light source the only electrical connection is the lead from the lamphouse, via a switch, to a convenient supply point. There should be enough slack cable or flex between the lamp and its nearest point of fixing to permit free movement of the enlarger head throughout its whole range. Usually the lead is taken through the top of the enlarger column, emerging at the bottom. This keeps the cable out of the way.

A neater way is to have a pair of current-carrying rails built into the enlarger column, with collectors in the supporting arm. This completely eliminates all trailing leads from the lamphouse. The live rail and the collectors must however be well recessed in the column to avoid all risk of being touched by the user.

The exposure is generally made by switching the lamp on and off for the required time. This is more convenient than having a shutter built into the optical system, since the shutter opening would still have to be timed by counting seconds, and shutter operation may induce vibration. (Very few shutters can be set to exposure times longer than about 1 second.) A shutter is however necessary with mercury arc lamps which have to stay alight all the time (page 137). Once switched off, they can be restarted only when cold. So the exposure is here controlled by a built-in shutter in the enlarger.

Some enlargers have the switch for the lamp built into the baseboard. This is neat, but vibration-prone. Ideally no part of the enlarger should be touched during the exposure; hence a separate switch in the lamp lead is preferable. This switch should be well away from the part of the wiring attached to the enlarger, so that it should be possible to pick up the switch without disturbing anything else. Alternatively, the enlarger lamp can be connected to a foot-switch on the ground underneath the enlarger table.

Most convenient of all is a timer wired into the enlarger lead to take the place of the switch. This then switches the lamp on and off automatically for a pre-set time.

Additional switches are of course necessary to control the elevating and focusing motors of a motorised enlarger. These can well be at the side of the baseboard, since they are only used during focusing and setting up. The exposing switch should still be separate.

Cold cathode tubes and certain other light sources need additional transformers and/or chokes. These may be mounted on the baseboard or other convenient parts of the enlarger. The exposing switch in this case should be between the transformer and the mains supply point, not between the transformer and the lamp. (The increased operating voltage – obtained from the transformer – may be too high for a normal control switch.)

CONSTANT VOLTAGE SUPPLIES

Tungsten lamps vary in their light output and the colour quality (colour temperature) of the light if the voltage applied to them changes. Precise exposure control in black-and-white enlarging and both exposure and colour control when enlarging colour negatives are therefore affected by voltage fluctuations in the supply. Hence for professional and colour work a constant voltage supply is desirable, which is independent of any fluctuations due to load variations in the mains supply.

The simplest way of achieving this is to connect the enlarger through a voltage stabiliser. This is a special transformer system which delivers a constant output voltage over a range of varying input voltages. Most convenient is an automatic stabiliser which adjusts the output voltage on its own. Somewhat simpler instruments require manual adjustment, the voltage being checked on a built-in voltmeter.

Automatic exposure control systems (page 280) for black-and-white enlargements do not always require voltage stabilisation. Here any decrease in light intensity is often compensated by an automatic increase in the exposure time. For colour enlargements automatic filtering compensation for changes in the colour temperature is less reliable. In any case, it is voltage changes between the time of taking an exposure reading and the time of making the print which upset the quality of the latter most.

THE ORANGE FILTER

Most enlargers incorporate a swivelling orange filter which can swing in front of the lens for locating the paper correctly on the baseboard prior to the exposure. Sometimes the filter is built into the enlarger head and moves into the light path inside the enlarger.

In either case the orange filter is not intended for focusing the image on the sensitive paper; the image itself is rarely brilliant enough for this purpose.

For professional operation the use of an orange filter of this kind wastes a lot of time. There it is better to locate the paper holder or masking frame precisely on the baseboard beforehand, and insert the paper in the frame in the dark.

The orange filter may however be useful for locating the image on the paper when making combination prints, printing in clouds etc. (page 482).

The filter should be large enough to cover the whole lens, without light spill around the edges. If the filter is too small it may be necessary to glue a cardboard panel – with a cut-out of the diameter of the filter glass – to the ring holding the filter. This panel then screens off any light that might come round the filter edge.

WEAK POINTS OF SOME ENLARGERS

Modern photographic apparatus has reached a high standard of efficiency and utility. That is true not only in the manufacture of cameras but also, with some exceptions and limitations, in the production of enlargers. While enlargers have features of varying quality and convenience as outlined so far, it is probably true to say that no enlarger has combined ideal features. This criticism is not directed primarily at precision, but at design points which could be improved at comparatively little cost yet still fall short of requirements for normal operating convenience. However, even where precision is concerned, many modern enlargers leave more to be desired than they should. Accuracy is obviously reflected in the price of the instrument, but the latter is not necessarily an indication of good design. At the best we can buy versatility – when we need it.

This is not to say that an enlarger must be a universal instrument. Though it is easier to envisage an enlarger than

a camera which covers efficiently a wide range of diverse demands, enlarger construction tends to be less adequate for the demands made on its use than modern camera construction. This applies especially to amateur enlargers – but unfortunately also to professional models. Let us consider for a moment how far the principles involved in and guiding camera construction apply to the enlarger as well. In the planning and design of a camera the most important object is to ensure that manipulation and setting should be as simple, easy and foolproof as possible. To this end scales are easily readable, controls easily accessible and moving parts made to adjust positively yet smoothly.

(1) A typical design shortcoming of many enlargers is the diaphragm and scale on the lens. Often the scale is difficult enough to read in a normally lit room, and quite impossible to see in ordinary darkroom lighting. The ring or lever which works the diaphragm is too small to see or even find easily. In addition iris scales in enlarging lenses frequently have grossly uneven intervals between successive settings of halving the light transmission.

Aperture scales on cameras have long been linearised with equal step-by-step intervals; the same should be possible without appreciable effort in enlarging lenses.

Click stops are the ideal diaphragm adjustment (page 146), but should still be supplemented by a scale. Lenses with an illuminated diaphragm scale exist, but are comparatively rare.

(2) As enlargers are operated in weak light, all controls which have to be found, seen and manipulated, should be of sufficient size and so designed as to facilitate easy and accurate setting. Ideally this means that the focusing, head adjustment and various clamping movements should have large and easily gripped knobs. If these knobs also vary in size and shape, they are more easily recognised by touch alone in the dark. Small milled screws and shafts are difficult to operate.

Equally inconvenient are controls hidden behind bellows or other fittings; fitting them with knobs at the end of extended shafts greatly improves accessibility.

(3) In camera construction great care is usually taken to ensure that all moving parts move easily and without undue friction. This is not always the case with enlargers. The

movement of the lamphouse on the stand is one of the commonest operations in enlarging, and one has a right to expect adequate provision for this movement. Yet not only in the cheapest but also in some of the medium-priced apparatus this particular adjustment is poor. Movement of the lamphouse often needs considerable effort and is difficult to fix securely. The weakest point is here the clamping arrangement on the sleeve carrying the enlarger head: moderate tightening of the clamping lever or knob still leaves the sleeve movable, while forceful tightening – often with considerable effort – may strip screw threads and need equal effort to slacken again when the head has to be raised or lowered.

(4) The firmness of the enlarger column, especially on the majority of amateur models, leaves a great deal to be desired. Often columns are too thin: a minimum thickness even for a 35 mm enlarger should be 4 cm or $1\frac{5}{8}$ inches. Nor is it either difficult or costly to brace the column to the baseboard by a pair of lightweight struts as illustrated on page 167. (In fact this additional and highly effective bracing can be carried out by any home constructor.)

(5) Looking at the inside of the enlarger head, the lamp fitting and the reflector behind it are often inadequate. To be effective, a reflector – even if only a matt white one – should have at least 4–5 times the diameter of the light bulb (this applies to semi-diffused illumination). Also it should curve down to come as nearly level with the lamp as possible.

For adequate electrical safety the enlarger should be earthed and the supply carried by a three-wire lead.

(6) The usual six-foot lead supplied with an enlarger is almost invariably too short, with the switch – halfway along the lead – in the worst possible place for easy access. Considering that an average small enlarger stands around $2\frac{1}{2}$ feet tall on a 3 foot work bench, the 6-foot lead could connect the enlarger to a power socket only if there is one part of the way up the wall immediately behind the bench.

Often it is wisest to rewire the enlarger with a new cable of adequate length to reach comfortably to the most convenient power point available, and situate a switch for easy access away from the enlarger itself. This may even be advisable if the enlarger has an exposing switch built into the

baseboard itself (page 172). Fortunately better professional enlargers are more generously equipped in this respect.

(7) The negative carrier of an enlarger has the important role of holding the film flat in the right place and without risk of damage. Yet negative carriers in many enlargers are very primitive, especially when compared with the film locating provision in even an inexpensive camera. Many film carriers have no provision for any lateral adjustment other than sliding the negative on the glass plate. At the most a projection rests against the side of the film to hold it in position. This applies particularly to film carriers for larger formats.

Even glassless negative carriers are often poorly finished: a couple of stamped out pieces of sheet metal are frequently considered adequate – until the rough edges have scratched a few films.

Centering single negatives in the mask of a carrier is unnecessarily laborious. The adjustable masking strips built into some enlargers (page 159) should be a universal feature. (They will also eliminate the need for separate masks in the negative carrier.)

(8) Continuing our critique of the enlarger, quite a number of models show far too many polished metal parts. However attractive these may appear to the untutored eye, they are very impractical, for they reflect light. Most obvious is usually the brightly chromium plated column or columns. During the exposure the enlarging paper surface reflects light. If any of this light is thrown back on to the paper by polished enlarger fittings, it will degrade the image and lower contrast.

Moisture and chemicals of the darkroom are also likely to affect bright metal parts by initiating corrosion. A matted stainless steel column is less reflective and more resistant to corrosion.

Equally illogical is the fact that the baseboard of many enlargers is light in colour. The projected image should never be focused directly on the easel, but always on a paper surface placed in the position of the bromide paper to be used. A dark or even black baseboard is more convenient, as it makes it easier to see and adjust the paper on it.

(9) It would also be of practical value to provide a cover of some description to protect the enlarger when not in use.

Plenty of advice is given on keeping apparatus clean, but perhaps the most effective source of dust and dirt is the time when the apparatus is standing idle in the darkroom. A dust-proof cover should be provided as a matter of course even with the cheapest enlargers.

(10) Finally, there is a tendency to promote the appeal of enlargers by designing them to be used as a piece of over-versatile photographic home equipment. Beside serving the actual purpose of enlarging, such instruments are also made to be used for a number of other specialised photographic processes. In a professional precision enlarger it is reasonable to provide features for photo copying and even micro-filming; in a comparatively inexpensive instrument such convertibility is usually achieved at the cost of reliability and precision in the work for which the enlarger is primarily designed.

The above remarks and criticisms are not only intended as hints towards the better design and equipment of enlargers but also as a guide when choosing apparatus before purchasing. They, and the analysis of enlarger features in this chapter, cover the mechanical side of enlarger construction. The functional aspects will be considered now in more detail in the next chapter.

The Choice of an Enlarger

The range of enlargers on the market today is so great that there is no point to attempt a detailed review of the various models. At first sight it also seems by no means easy to choose a suitable one for personal requirements. The choice is simplified by considering the following factors:

(1) Negative size;

(2) Maximum degree of enlargement;

(3) Purpose (i.e. amateur, professional or specialised work) and facilities of additional convenience or versatility.

NEGATIVE SIZE

The largest negative size an enlarger will take is determined on the one hand by the dimensions of the negative carrier and lighting system, and on the other by the focal length of the lens (see also Table X on page 143). The maximum degree of enlargement on the other hand depends on the maximum height of the negative above the enlarger baseboard – usually in effect the height of the enlarger column – and again on the focal length of the lens employed. This relationship is shown in Table IX on page 143.

Obviously an enlarger suitable for a given negative size can equally enlarge negatives of smaller format. In that sense an enlarger for, for instance, 6 × 9 cm negatives is suitable also for 24 × 36 mm or smaller miniature or subminiature films. But a big format enlarger is not the most economical or efficient proposition for a small negative.

The reason emerges fairly clearly from the points already made on page 141. Small negatives generally need a greater degree of enlargement than big ones. To reach a print size of 30 × 40 cm or 12 × 15 inches, a miniature enlarger for 24 × 36 mm negatives has to be capable of a manification of at least 12 times – which calls for a column about 2½ to 3 feet high with a 50–60 mm lens. A 6 × 6 cm negative needs enlarging about 7 diameters, and a 75–90 mm lens

will do this with a column of the same height. With a 6×9 cm or $2\frac{1}{4} \times 3\frac{1}{4}$ inch negative the corresponding magnification would be around 5–6 diameters, once more obtainable with a similar height of the negative above the baseboard, when using a 100–105 mm lens.

These maximum magnifications, depending only on the lens and the enlarger height, remain the same, even when a 24×36 mm negative is enlarged in a 6×9 cm or $2\frac{1}{4} \times 3\frac{1}{4}$ inch enlarger. So in the latter case the maximum magnification of say 6 diameters yields a print no larger than 6×9 inches.

The obvious way out of this dilemma is to have interchangeable enlarging lenses, matching the focal length to the negative size being enlarged, as listed in Table X on page 143. This facility is indeed available on many simple enlargers intended for several negative formats. Most enlargers have a lens panel taking a standard screw flange which in turn accepts screw mounted enlarging lenses. The interchangeability of the lens means not only that different focal lengths, but also lenses of different make (and price) can be selected for a given enlarger.

In theory this type of convertibility could be extended to enlargers for quite big negative sizes. In practice there are several difficulties which – though not impossible to overcome – render working with small negatives in big enlargers a little inconvenient. This applies especially to ultra-miniature negatives handled in enlargers designed for formats bigger than 24×36 mm, and for instance 35 mm negatives in 4×5 inch, 13×18 cm or larger models.

The first point is a design problem of the negative carrier. Obviously this has to be large enough to accommodate the biggest format. And a carrier taking 13×18 cm or 5×7 inch negatives sandwiched between glass is not necessarily convenient for handling 35 mm film strips. The very width of the carrier would make it impossible for instance to position or reposition a four-negative strip of 24×36 mm images without removing the carrier from the enlarger every time. This applies even if the enlarger has a special 35 mm glassless carrier – the films simply are more convenient to handle in a smaller negative carrier of a smaller format enlarger. (This applies especially when dealing with ultra-miniature negatives – see page 184.)

Secondly, the bellows or other focusing movement of the enlarger must be capable of bringing the appropriate short focus enlarger lens near enough to the negative for big magnifications. Often the design requirements of a big format enlarger (adequate rigidity of the movement etc.) make this difficult. One solution in such a case is to use a recessed lens panel to hold a shorter focus enlarging lens higher up in the enlarger (page 149).

Thirdly, a big-format enlarger, designed to illuminate evenly a large negative area, obviously wastes a lot of light if only a small area of the negative carrier is utilised. When the enlarger works with diffused illumination, the light intensity at the high magnifications required for miniature negatives may be so low as to call for excessively long exposure times.

One solution, suitable for diffused light enlargers with an integrating sphere, is to have a range of interchangeable spheres or interchangeable mixing boxes (page 124). The smaller the sphere or box – with the light from the same lamps concentrated into it – the more intense becomes of course the illumination over a smaller negative.

This problem arises even with condenser enlargers, and is overcome in some multi-format models by interchangeable condensers and/or interchangeable lighting units. Thus a cold cathode lamp head may be employed for the larger negative formats, and a condenser lamphouse for the smaller ones. Alternative condensers may run in sliding drawers.

A condenser system of shorter focal length concentrates more light on to a smaller negative area and also fills the lens area more efficiently (page 126). Where however the light source is sufficiently powerful, we can trade lighting efficiency for the convenience of making do with one set of condensers over quite a range of negative formats (for example from 35 mm up to 4 × 5 inches). Since the lamphouse of a good quality big format enlarger is designed to dissipate efficiently the heat produced, this is no problem with smaller format negatives either.

MULTI-FORMAT ENLARGERS

Where a range of negative sizes is in use, it is quite practical to accommodate them with one enlarger – with alternative enlarging lenses – provided the biggest format is not more than four times as large in area as the smallest. Thus a

6×9 cm model is perfectly suitable for negatives down to 24×36 mm; a 4×5 inch enlarger for negatives down to 6×6 cm, and so on. If the discrepancy between the negative sizes to be accommodated is greater than this, it is usually more convenient to have two separate enlargers to deal with the large and the small negatives. This indeed is standard practice in professional darkrooms.

Within this range advanced multi-format enlargers offer however certain refinements for rapid changing over and working. We have already mentioned interchangeable condensers and lamp units (page 181). For rapid lens changing some enlargers also feature a two- or three-lens turret.

The two-lens turret may carry a 50–60 mm and a 100–110 mm lens (for a 35 mm to $2\frac{1}{4} \times 3\frac{1}{4}$ inch enlarger) on a sliding panel. Three-lens turrets are more usual for wide-range enlargers to cover for instance 35 mm to 4×5 inch negatives or 6×9 to 13×18 cm ($2\frac{1}{4} \times 3\frac{1}{4}$ to 5×7 inch) formats. The focal lengths would here range from 50 to 210 mm.

Advanced multi-format enlargers of this kind may also incorporate automatic focusing for two or even three focal lengths of lens. This involves the use of two or three cams, as the case may be, with the focusing movement being changed over from one cam to the other at the same time as the lenses are switched. The cams must of course match the exact focal length of the individual lenses fitted.

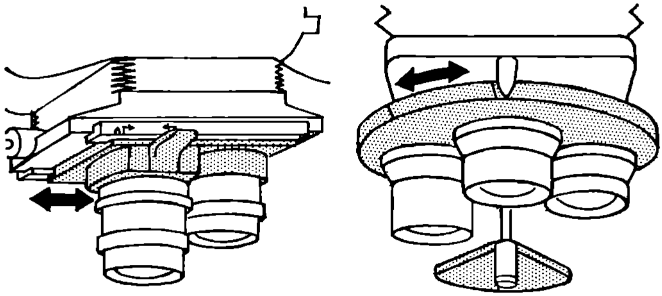
AMATEUR ENLARGER FEATURES

The majority of amateur enlargers take negative sizes ranging from 24×36 mm to 6×9 cm or $2\frac{1}{4} \times 3\frac{1}{4}$ inches. They are mostly simpler instruments, using a single (or sometimes double) straight or inclined column, straightforward lamphouse with single or double condenser and 75–150 watt lamp. The usual focusing movement is either a helical tube or a bellows movement with a rack and pinion or friction drive.

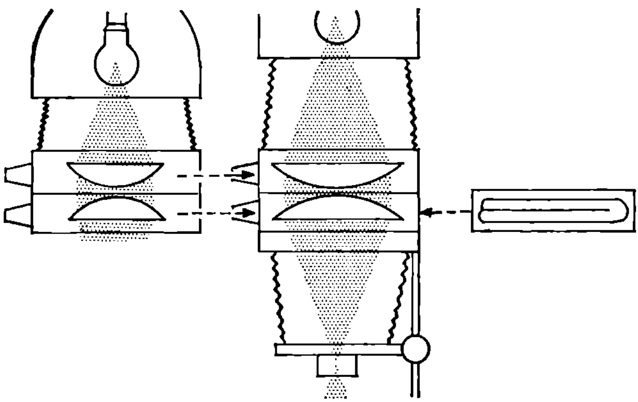
The adjustment of the enlarger arm is usually a clamping sleeve (page 168), though friction or gear drives are also used. Some amateur enlargers, especially in the 35 mm. size, have parallelogram movements for the lamphouse.

The enlargers for 6×6 and 6×9 cm ($2\frac{1}{4} \times 2\frac{1}{4}$ and $2\frac{1}{4} \times 3\frac{1}{4}$ inch) negatives usually take interchangeable lenses

MULTI-FORMAT ENLARGER FEATURES



To cover appreciably different negative sizes, lenses of different focal lengths are necessary. More advanced multi-format enlargers carry lens slides (*left*) or turrets (*right*) to speed up lens changing.



For most efficient light utilisation, the condenser and lamphouse dimensions should be appropriate to the negative size. Thus small negatives need smaller condensers and a nearer lamp (*left*); larger negatives need bigger condensers and a different lamp position to cover the format uniformly. In professional enlargers condensers are often interchangeable. Sometimes they can also be replaced by a cold cathode grid for diffused illumination of large formats (*right*).

of different focal lengths to provide a greater magnification range with smaller negative formats.

Inexpensive models in the lowest price class may have diffused lighting and a fixed lens of smallish aperture.

Larger format amateur enlargers (maximum negative size usually 4 × 5 inches) mostly utilise diffused illumination with one or more lamps and an opal glass screen.

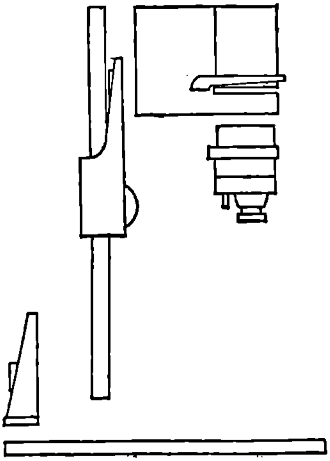
Amateur models also include folding enlargers, usually for negatives up to 24 × 36 mm, which pack into a fairly small-size suit case. This possibility is achieved by keeping the dimensions of the baseboard comparatively small (down to as little as 25 × 30 cm or 10 × 12 inches) and the column short. The latter is easily detachable from the baseboard so reducing the storage bulk of the enlarger to a minimum.

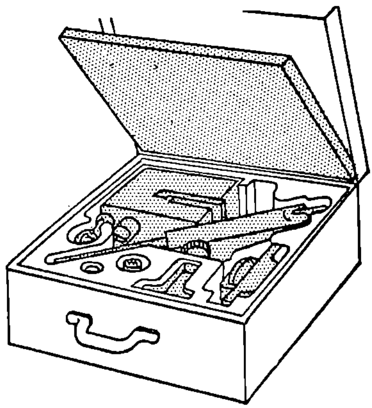
ULTRA-MINIATURE ENLARGERS

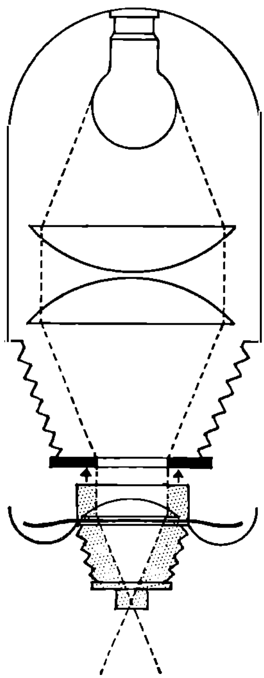
For the reasons already stated on page 180 (the inconvenience of handling strips of tiny negative in a large carrier, and the difficulty of getting a short focus lens near enough to the negative plane) enlargements from ultra-miniature and "pocket" format negatives from 8 × 11 to 13 × 17 mm usually require special instruments. With a normal 35 mm enlarger the limiting magnification of 12–15 diameters only yields a print of about 10 × 12·7 cm or 4 × 5 inches. A number of modern miniature enlargers however provide special negative carriers for ultra miniature film strips, provision for fitting a shorter focus (say 25 mm) lens and possibly alternative condensers to concentrate the light more effectively on the small negative format.

There are two other ways. The first is an ultra-miniature enlarger proper, which is in effect a scaled-down version of a normal 35 mm enlarger. Employing lenses of focal length from 15 to 30 mm, these permit magnifications of about 15 to 30 times, i.e. prints up to 40 × 50 cm. As the lamphouse is also rather small, some ultra-miniature enlargers use a tungsten-hologen lamp bulb of low voltage, fed through a transformer. Condensed or diffused light may be used; as the extreme magnification is liable to show up scratches as well as grain, diffused lighting is often preferable here.

The second possibility is an adapter for a normal miniature or medium format enlarger. This adapter fits into the lens







Above: Suitcase enlargers – usually small size models – are easily dismantled into parts which pack conveniently into a portable case.

Right: Miniature and medium sized enlargers can sometimes be adapted to ultra miniature negatives by an attachment which fits into the lens panel in place of the lens. This attachment contains its own condenser lens, negative carrier, focusing movement and enlarging lens. The light source becomes the beam of light projected through the opening in the main enlarger lens panel.

flange of the enlarger in place of the normal lens and consists of a condenser system, negative carrier and short focus (about 25 mm) enlarging lens. The light beam projected by the enlarger into the plane of the lens panel becomes in effect the light source for the adapter.

The advantage of this arrangement is that on the one hand the negative carrier and lens focusing movement are easily accessible, while on the other high magnifications are still possible owing to the considerable column height (for such a small negative format) and comparatively large baseboard of the main enlarger.

PROFESSIONAL MINIATURE AND MEDIUM-FORMAT ENLARGERS

While the basic principle of the enlarger is naturally the same, whether it serves for simple or more advanced amateur and professional purposes, the advanced enlarger usually has a number of features to increase working convenience, versatility and often also robustness.

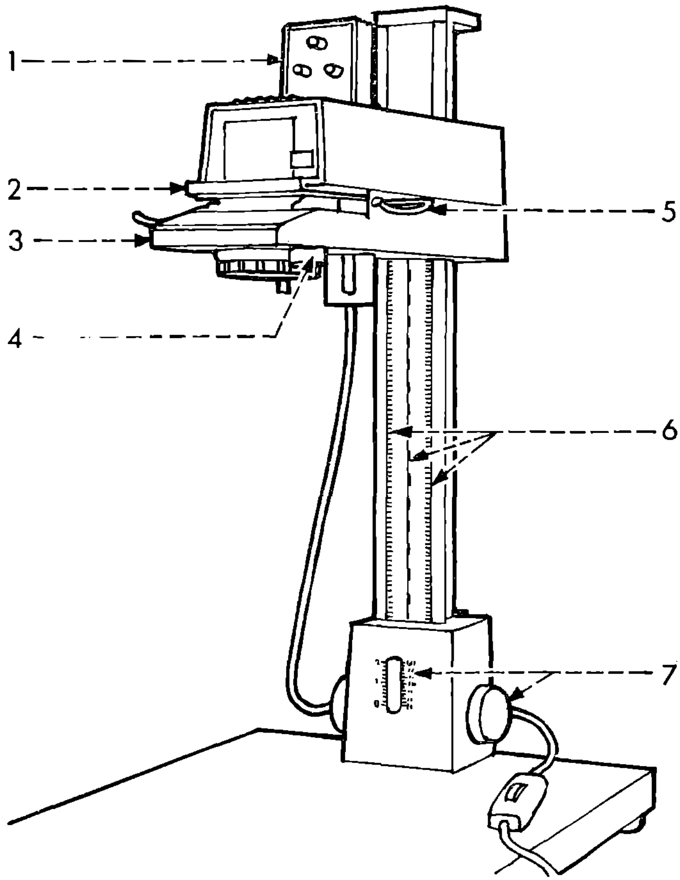
Such enlargers therefore incorporate many of the following special features:

More rigid column structures and higher columns provide a greater magnification range with less risk of vibration.

Larger and well-ventilated lamphouses permit more powerful light sources for short exposures at high magnifications. Often the lamphouse itself is interchangeable to permit the use of different light sources or of colour heads (page 305). In most cases there is at least provision for taking colour filters (e.g. a filter drawer – page 202) for colour enlargements.

Automatic focusing systems (page 152) greatly speed up working when frequent changes of magnification are required. For greater convenience the raising and lowering of the enlarger head may use either a parallelogram system (page 171) or may be controlled by hand wheels on the baseboard. In the case of non-automatic enlargers remote focusing – again with a control on the baseboard – obviates the need for adjusting the lens directly on the enlarger. An additional feature on some models is a magnification indicator, linked with the movement of the enlarger head.

Negative carriers are usually interchangeable for different film sizes and may provide automatic release of pressure for



The professional 35 mm. enlarger differs from its simpler amateur counterpart not merely in precision (a simple enlarger can still be very precise) but in the additional controls and features for special jobs. Some of these special controls (in this case on the Durst A 300) are: 1, colour mixing head with individual filter control (replaces normal lighting system of enlarger for colour work); 2, negative carrier locking bar, raised to permit film movement; 3, hand grip and lock for raising and lowering the enlarger on the column. Pressing the grip releases the lock; during the vertical movement an automatic focusing system keeps the image on the baseboard sharp; 4, control for red filter; 5, film wings; 6, scales on column (magnification, cm and inch scales); 7, compensation for paper holder height with automatic focusing. Advanced enlargers of similar type may also include a magnification indicator, provide for tilting the enlarger head and/or lens, take a copying film magazine, etc.

rapidly moving a strip of film from one negative to another.

Many professional enlargers have tilting negative carriers for distortion control (page 162) or provision for fitting a tilting stage.

Professional enlargers invariably have interchangeable lenses; on medium format models the lens change may be semi-automatic by means of a lens turret (page 182), sometimes coupled with an automatic switching over of focusing cams.

Accessories for enlargers in this group include extension units for same-size enlargement or reduction, and copying gear to turn the enlarger into a copying camera. The necessary items here are a film magazine which fits into the enlarger head in place of the negative carrier (possibly after removal of the lamphouse) and a lamp unit for even illumination of originals to be copied, placed on the baseboard.

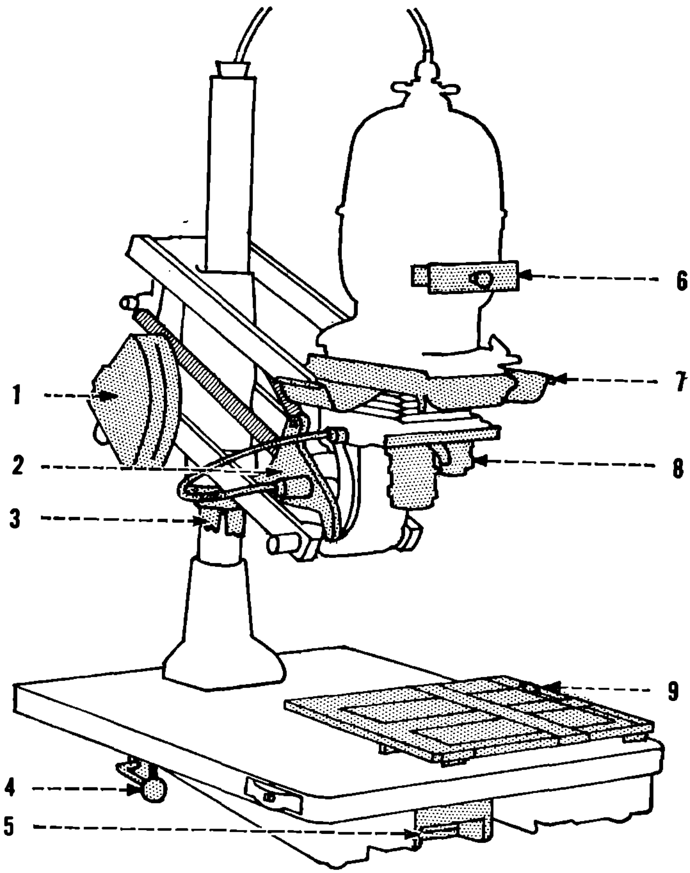
Strictly speaking, conversion to a copying camera is not an enlarger feature that need be regarded as necessary – or in cheaper models even as desirable. Any professional photographer whose work covers a great deal of copying and microfilming, is better served with a special copying camera. However an enlarger conversion for this purpose is useful where only occasional copying jobs crop up – provided that the enlarger construction satisfies the high requirements of precision demanded of a copying set-up.

This is much more important when reducing originals 15–20 times on microfilm stock than when enlarging a miniature negative in the same proportion. In the former case insufficient precision leads in the microfilm image to an irretrievable loss of important detail. In enlarging from a pictorial miniature negative a less than perfect enlarger loses definition – which may be merely irritating but often not even too obvious when a big enlargement is viewed from an appropriate distance.

LARGE-FORMAT PROFESSIONAL ENLARGERS

In their simpler form these instruments are scaled up versions of medium format enlargers, taking negatives of 9 × 12 to 18 × 24 cm or 4 × 5 to 8 × 10 inches. The scaling up process need in principle be no more than the provision of bigger baseboards, higher columns, larger

PROFESSIONAL MEDIUM SIZE ENLARGER



Medium format enlargers are often dual format instruments, for instance for roll film and miniature films, fitted with interchangeable lenses on a turret or slide. Typical features (here of the Focomat IIc) are: 1, illuminated magnification indicator; 2, focusing cam system with automatic cam change by a Bowden cable; 3, height compensation for masking frames of different thickness; 4, location locking lever for masking frame 9; 5, pull-out light box for visual check when inserting negatives in carrier; 6, filter drawer; 7, negative carrier (can be changed for a tilting device); 8, lens slide with two lenses for miniature and medium format negatives; 9, masking frame locked anywhere in position by lever 4.

negative carriers and condensers, and longer focus lenses. In practice the equipment of a professional large format enlarger however often goes considerably further.

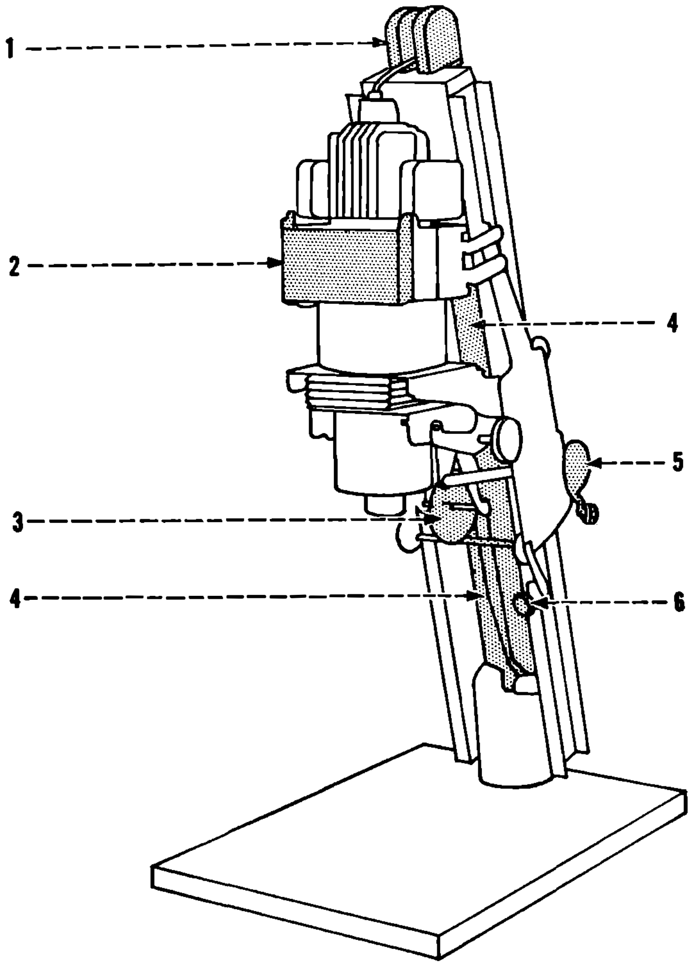
The enlargers themselves may be bench or stand models. The bench versions, usually for negatives up to 4 × 5 inches (occasionally up to 13 × 18 cm) are still built up on the baseboard plus column principle. Where single columns are used, these are specially thick and often braced to reduce vibration (see also page 168). More often multiple columns are employed and serve at the same time as guide rails for the almost indispensable counterweight for raising and lowering the enlarger head. For greater stability the column has often facilities for anchoring to the darkroom wall.

Floor models abandon the traditional baseboard mounted column set-up in favour of a single or multiple column on a pedestal, possibly anchored in addition to the wall or ceiling (see also page 165). This column carries both the enlarger head and the baseboard on separate arms. Accordingly, both may be adjustable in height. This gives the enlarger the full height which a bench model would achieve by swinging the head around on its column and projecting on the floor. Further, a baseboard mounted on an arm is easier to tilt for distortion control, than one which rests on a flat bench top and carries the whole weight of the instrument.

While professional bench enlargers often provide automatic focusing over the most frequently used magnification range, floor models generally go back to manual focusing. This is partly because the greater magnification range – especially with a variety of formats and enlarger lenses – is not so easy to cover by automatic focusing. The enlarger is indeed more versatile (even if not quite so convenient) without this automatic feature. Also, automatic focusing is only practical with a fixed, and not a movable baseboard.

With enlargers for negatives to 20 × 25 cm (8 × 10 inches) the baseboard may be up to 30 × 40 inches large, and the enlarger head 2·5 m or 8 feet above the floor. Since reaching the lens for focusing, and moving the enlarger head up and down (even with the counterweight) requires more than average acrobatic ability, many such models feature remote control for the heavy adjustments. This may be

10 × 12·7 CM OR 4 × 5 INCH BENCH ENLARGER



Professional bigger format enlargers for standing on the bench are essentially scaled-up versions of medium format instruments, usually of specially rugged build to ensure rigidity. Typical salient features are: 1, counterbalance mechanism to carry the weight of the lamphouse; 2, variable condenser system to match different lenses; 3, cam follower of automatic focusing movement; 4, multiple focusing cams for different lenses; 5, hand crank drive of enlarger head; 6, locking knob of head movement.

either manual with hand wheels or knobs below the baseboard, or motorised (see also page 170).

Since big-format enlargers generally try to cover a fairly wide range of negative sizes – even though this is not necessarily an advantage from a design point of view (page 180)—lamphouse units are very frequently interchangeable. Hence cold cathode grids, condenser units with tungsten lamps and other lighting systems may be switched round to cover the different picture formats with maximum efficiency. Interchangeable heads also permit the fitting of colour mixing heads for colour enlargements. In fact most professional enlargers have some provision for colour control of the illumination – see also page 199.

REGISTRATION

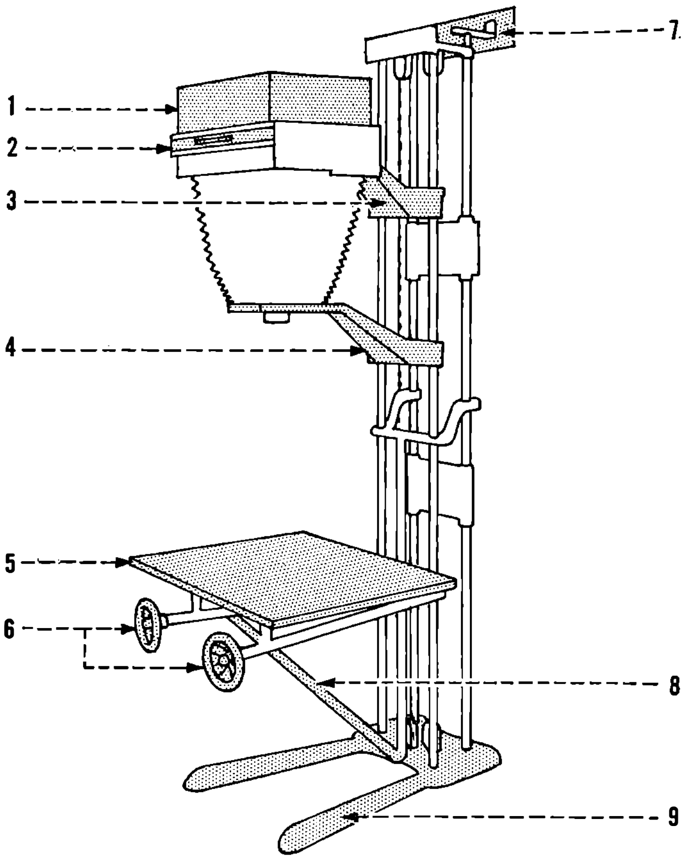
Big format enlargers (negatives from 13 × 18 cm or 5 × 7 inches up) also find certain uses in the graphic arts field, for making half-tone and colour separation negatives, duplicates enlarged or reduced copy negatives or positives etc. The technicalities of graphic art procedures need not concern us here, but certain requirements for graphic arts enlargers are useful also for some advanced professional enlarging techniques.

Of particular significance are provisions for accurate and repeatable location of the negative or the positive material (or both) in the negative carrier and on the baseboard respectively. This is useful for various combination printing techniques as well as tone separation and other processes which require accurately predictable location or even precise superimposition in register of different images during printing. The techniques themselves are described on pages 408 and 470; at this point we shall look at the specific enlarger features to facilitate such procedures.

The basis of accurate location of the negative and positive material is the punch register system. Here two holes are punched along one edge of the material to be located (negative film or paper etc.) and the sheet placed with its holes over a couple of pins. These relocate the sheet in exactly the same place if it has to be removed between successive handling stages or locate successive sheets (such as negatives) in the same place for accurate superimposition.

The punch register arrangement therefore consists of two parts: the punch itself and the register pins. These in turn

GIANT PROFESSIONAL ENLARGER



Models for negatives up to 8 × 10 inches or larger are almost invariably pedestal types, with considerable adjustability but less frequently automatic features. This is a typical all-manual example: 1, interchangeable lamphouse (cold cathode grid etc.); 2, negative carrier; 3, 4, separately mounted runners (counterweighted and chain driven) for the negative and lens stages (the former with the lamphouse) 5, adjustable easel; 6, hand wheels for lamphouse and lens adjustment; 9, wall mounting of column support; 8, adjustable easel support; 7, pedestal base.

can be located in the negative carrier, on the baseboard or in both places.

Register pins in the negative carrier serve for locating successive negatives (or transparencies) which have to be projected superimposed on one sheet of positive material. The appropriate films are in this case accurately registered over a viewing light, trimmed in register along one edge (obviously one containing spare film area rather than necessary picture detail) and punched along that edge.

The punch for this purpose works in much the same way as an office punch, though the shape of the holes and their spacing is not the same. Usually one hole is round or barrel-shaped to fit exactly over one register pin, while the other hole is elongated to prevent buckling of the film as a result of slight shrinkage or expansion (for example due to processing between the punching and the registering stages). If the film is now placed on the register pins in the negative carrier, the image is always located – and relocated – in exactly the same place relative to the carrier.

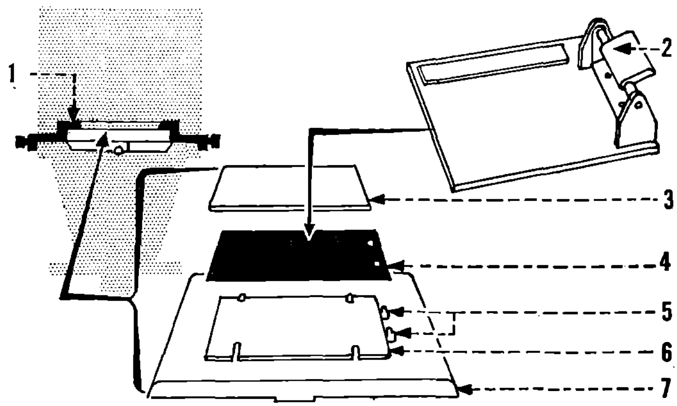
For absolutely precise location in the enlarger itself, such a registering carrier consists of two parts: a holding frame and the negative carrier itself. The holding frame is fixed in the film stage of the enlarger, and ensures that the negative carrier is always located in precisely the same place in the negative stage.

With some enlargers the same negative carrier can be converted into a sheet film holder, and used in this case for making for instance separation negatives from colour originals. By punching and locating the separation films in the manner described, each negative – taken through a red, green and blue filter respectively, is accurately located for subsequent registration in printing.

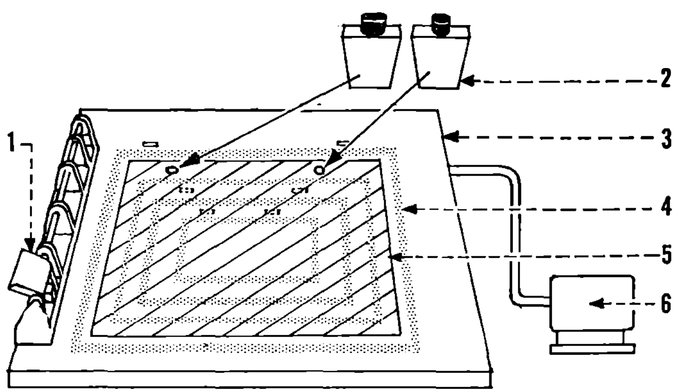
Register pins on the baseboard serve a similar purpose for locating successive sheets of printing material with the projected image from a given negative always in the same place.

On some graphic arts enlargers register pins are built into the easel and can be raised when required or lowered flush with the surface when not needed. Some enlarger easels have several such pins located at different points to take printing materials of different sizes.

A pin register system on a baseboard can however also



For accurate location of negatives in the enlarger a locating carrier with register pins may be used. 1, locating guides to hold the negative carrier accurately in place in the enlarger; 2, register punch for punching films; 3, top plate; 4, negative; 5, register pins; 6, bottom plate; 7, negative carrier. See also page 188.



Vacuum baseboard with locating pins (page 191). 1, register punch; 2, register pins (can be placed in slots provided in the baseboard); 3, baseboard; 4, vacuum channels; 5, punched paper (or film) placed on register pins; 6, vacuum pump.

be improvised by fixing a thin bar carrying a pair of register pins to the baseboard.

These pin register bars are available from certain photographic manufacturers.

VACUUM EASELS

Graphic arts enlargers may provide – sometimes as an optional feature – a vacuum baseboard to hold papers or films absolutely flat. The baseboard here carries on its surface a network of grooves connected with a suction pump. The latter draws air through the grooves and thus pulls down flat any sheet of film or paper on the easel.

The grooves or channels usually form a series of rectangles one inside the other. The channels to be connected to the pump can be selected from the innermost one outwards. This enables small as well as large sheets to be held in place by suction. (With a small sheet the outer channels which are not covered by the sheet have to be blocked off from the pump as otherwise the inner channels would not be under a sufficient suction.) The vacuum easel may also incorporate register pins as described above. Vacuum easels are even available on their own and may be placed on a normal baseboard.

The main uses of such a vacuum easel are:

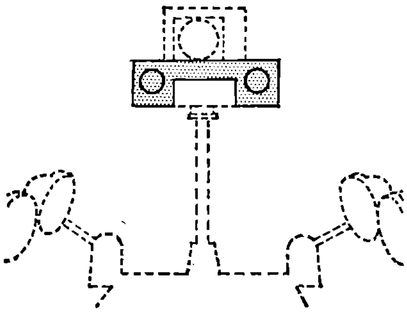
(a) Keeping large sheets of printing material absolutely flat without glass plates, pins or other aids;

(b) Holding the material firmly in place once it is sucked on to the board;

(c) Pressing two sheets of material into intimate contact. This is used in graphic arts practice for making half-tone negatives or positives by projecting the negative in the enlarger on to the printing emulsion through a half-tone contact screen placed in contact with the emulsion. Equally, the vacuum easel can be used as a contact printer, for example when making duplicate negatives or positives etc. In this case the light through the enlarger lens (without a negative in the carrier) serves as the printing source.

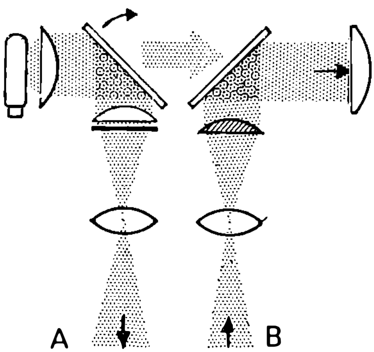
COPYING FILM HOLDERS

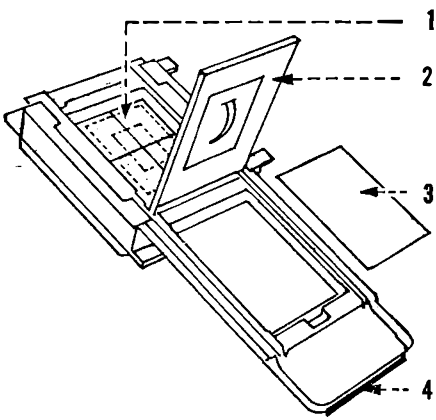
Like advanced 35 mm enlargers, big format instruments



Some miniature enlargers permit the insertion of a copying cassette holding 35 mm film in place of the negative carrier. This cassette takes 35 mm film in bulk lengths for microfilming.

Two-way optical systems for enlarging and copying. A flipover 45° mirror controls the light path. For enlarging (A) the light from the lamp goes through the negative and the enlarging lens to the paper. For copying (B) the mirror is swung round and the image of the original on the baseboard focused on a screen in the film plane. This is observed via a field lens.





Copying cassettes for plates and sheet films. This is intended for bigger enlargers and again takes the place of the negative carrier. A sliding stage brings either a ground glass screen (with format frames) or the copying film into the focal plane of the enlarger. With the screen in position, the frames (and focusing marks) are projected on the original to be copied. 1, screen, 2, lid of film holder; 3, backing plate (when using sheet films); 4, dark slide.

frequently have provision for use as a copying camera. This involves replacing the negative carrier by a light-tight sheet film holder. To permit accurate focusing of the image a ground glass screen with focusing marks may be inserted in the negative stage. These marks are projected on a sheet of paper on the baseboard, in the plane of the original to be copied. When the marks are sharp on the paper, the enlarger is correctly focused. Boundary frames may indicate the field taken in on the film of different formats.

For the exposure a dark slide takes the place of the ground glass screen, the film in which is in the same plane as the focusing marks on the ground glass screen. The exposure is made by switching on lamps illuminating the original on the baseboard, while the enlarger light is switched off. For the exposure the dark slide of the copying film holder is of course pulled out.

With some enlargers the ground glass screen and the copying dark slide are combined in a sliding stage which only needs moving across the negative stage to replace the screen by the film holder.

An alternative arrangement, used in some enlargers incorporating a 45° mirror in the lighting system, uses that mirror for observation of the image on the ground glass screen while the original is being illuminated by the copying lamps. The film holder – which may incorporate registering pins – then replaces the ground glass screen for the exposure.

Certain graphic arts enlargers permit the use of a xenon flash tube or a pulsed xenon arc as the light source in a special lamphouse.

ADAPTING A CAMERA AS AN ENLARGER

An enlarger is, as we have stated, "a camera in reverse". So it should be possible in principle to use a camera as part of an enlarger. This indeed used to be the solution adopted for cheap enlarger units: the enlarger as such consisted of a lamphouse (for diffused illumination) to which the camera could be attached. This lamphouse then moved along a vertical (or in even simpler models a horizontal) column with an easel at the other end.

Such an arrangement is possible only with cameras which have (1) a suitable focusing movement – usually bellows

with a rack and pinion movement; and (2) access to the camera back to permit insertion of negatives in a plane not too far behind the focal plane of the camera.

Adapter units of this kind are therefore usable with plate cameras and certain older types of roll film camera. They are not suitable for rigid cameras or 35 mm models. The focusing scope here is inadequate for a useful enlarging range and often the negative cannot be inserted in a plane near enough to the focal plane of the camera.

Special conversion outfits exist for selected technical cameras, where such camera outfits include copying gear (with baseboard and column) in their accessories. There the requirements of an enlarger and of the copying camera are sufficiently similar to make the conversion possible. This however involves specially designed lamphouses for the camera model – and even then the operational camera features and controls are not necessarily ideally placed for enlarging use.

COLOUR ENLARGERS

In a black-and-white enlarger we are concerned with enlarger illumination in terms of intensity, evenness and direction or diffusion. For colour enlarging we have to worry in addition about the colour of the light.

The colour values of the negative have to record in the blue-, green- and red-sensitive layers of the colour paper. So the light source used in the colour enlarger must have a sufficiently continuous spectral emission to contain broad bands of blue, green and red radiation. Tungsten and tungsten-halogen lamps are satisfactory in this respect, but cold cathode lighting may not be so.

Before employing a cold cathode source, preliminary tests have to establish whether its light is capable of yielding correct colour prints – and of being controlled predictably by colour filters (see below). A cold cathode source suitable for one type of colour negative and colour paper may not be so good for another combination. High intensity mercury vapour lamps are not suitable for colour enlarging.

Further, the colour of the enlarging light has to be adjustable. We control the quality of the colour print by balancing the extent to which the images are formed in each of the

three layers of the colour paper. Such adjustment is necessary because:

(a) Different enlargers vary in the precise colour quality of their illumination (caused not only by the enlarger lamp but also by selective light absorption in condensers, diffusers etc.);

(b) The exact sensitivity balance between the three layers of a colour paper varies not only with different types of paper, but also with different batches of the same material;

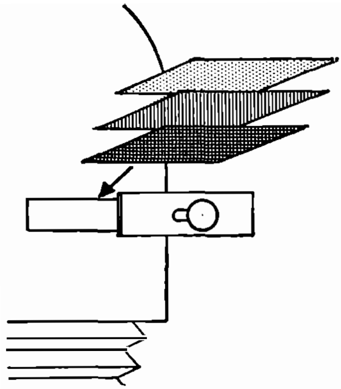
(c) The exact colour balance of the colour negative depends on the dyes used in the negative material. For a given negative film individual negatives may differ in colour balance according to the light by which they have been exposed (daylight, flash etc.) and the way in which they have been processed. (The latter should be constant, but is not always so.)

There are two methods of controlling the way in which the light coming through the colour negative forms its images in the three layers of the colour paper.

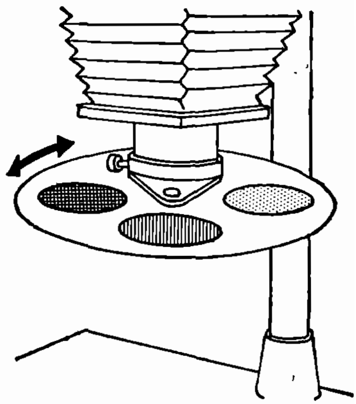
The first involves modifying the proportions of blue, green and red in the exposing light. Thus if the colour rendering of the print appears too yellowish, the yellow forming (blue-sensitive) layer of the paper has produced too strong an image. We can correct that by reducing the proportion of blue in the exposing light – generally by placing a pale yellow filter in the light path. In the same way we may have to reduce the green component with a magenta filter (which absorbs some green) or the red component with a blue-green (cyan) filter. Often we have to adjust the light with filters of two colours and of different depths.

In principle the print is however made with a single exposure, using modified white light. So this method is known as single exposure or white light printing – or subtractive printing, since the filters subtract or hold back specified colour proportions from the light.

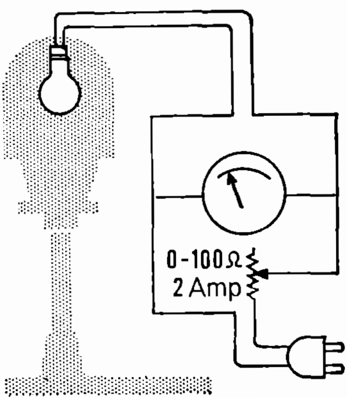
The alternative way is to expose each layer of the colour paper by a light to which only that layer is sensitive. This involves printing the colour negative in succession through



The simplest means of controlling the colour of the enlarging light for subtractive printing is a filter drawer. This is fitted in the lamphouse above the condenser lenses and takes printing filters of the required depth and colour combination in sheet form.



For additive (three-exposure) printing the required red, green and blue filters may be arranged below the lens on a rotating turret. The exposures are made successively through the three filters in turn.



A simple way of keeping the voltage of the enlarger lamp (and hence the colour of the light) constant uses a voltmeter across the mains supply and a variable resistor in series with it. For a 150–250 watt lamp this resistor should have a range from 0 to 75 ohms (or 0 to 100 ohms for 100–250 watt lamps) and should carry 2 amps for lamps up to 250 watts. These values apply to 220–240 volt mains; for 110–120 volt supplies the resistance values can be halved, but the current carrying capacity must be doubled.

a deep blue, a deep green and a deep red filter, and controlling the colour balance by an appropriate choice of the three exposure times. This is therefore the method of three-exposure or tri-colour printing, also known as additive printing, since the exposures are added together.

There are various theoretical and – more important – practical advantages for each method. We shall come back to those on page 282. For the moment we are concerned with the colour enlargers used for them.

The simplest adaptation for white light colour enlarging is a filter drawer. This is a sliding drawer built into the lamphouse – usually above the condensers, where fitted – to take yellow, magenta or cyan correction filters in various combinations. These filters are stacked on top of each other in the drawer which inserts them in the light path of the enlarger before the light reaches the negative.

Since the filter drawer is a comparatively simple fitment, most professional and many amateur enlargers are provided with it. The filters have to be large enough to cover the condenser area, and usual sizes are $4\frac{3}{4} \times 4\frac{3}{4}$ inches (12×12 cm) for medium format enlargers up to $2\frac{1}{4} \times 3\frac{1}{4}$ inch (6×9 cm) negatives, and $2\frac{3}{4} \times 2\frac{3}{4}$ inches (7×7 cm) for miniature enlargers. Filters for single exposure printing are not placed in front of the enlarger lens, since up to 4–6 filters may be required simultaneously. Such a stack would in that position impair both definition and contrast (owing to intersurface reflections) of the image.

Adapting an enlarger for three-exposure printing is simpler, since only three filters are involved and they are placed in the light path one at a time. Here the best position is in front of the lens, for the filters have to be accessible for changing during an exposure sequence and without the risk of moving the enlarger head. A filter slide or filter turret are the most usual fittings, and can be attached to any normal enlarger.

More advanced colour enlargers (page 304) may have a motor-driven filter changing system built into the enlarger lamphouse between the lamp and the condenser. Special colour enlargers for single exposure printing modify the light colour by inserting yellow, magenta and cyan filters to different degrees into the light path.

Since the dye images of a colour negative have a very low scattering or Callier factor (page 128) the type of lighting employed does not appreciably affect image contrast. The only drawback of point source lighting with a condenser remains the fact that this strongly shows up scratches and dust on the negative. Point source lighting is however popular in some colour enlargers, as its greater intensity permits shorter enlarging exposures. This is a point of some importance in tri-colour printing with its three successive exposures.

For white-light printing, thorough mixture of the light – especially when filters protrude only part of the way into the beam – is essential before the light reaches the negative. Such enlargers therefore often use diffusing systems, for example of the integrating sphere type (page 124). A high-intensity enlarging lamp is however usually desirable, partly because of the loss of light through the diffusing system and partly because the correction filters further increase the required exposure.

Three further points are relevant:

(1) As fluctuations in mains voltage affect both the colour and the intensity of the light, some form of voltage regulator should be installed in the lamp circuit. This must permit adjustment of the voltage to a standard value immediately before making each exposure. The maximum permissible voltage variation without serious effect on results is an average of ± 2 per cent – i.e. less than 5 volts each way when working at 240 volts. A voltage stabiliser (page 201) is better still.

(2) Most good-quality enlarging lenses are suitable for colour work. They should be coated (page 147).

(3) Stray light from the lamphouse, negative carrier etc. must be carefully avoided. The enlarger should not be used close against a light wall which may reflect light on to the paper during exposure. This is of course also important for black-and-white enlargements. In colour work stray light is even more harmful because it may cause colour casts, and it has more chance of fogging the paper during the longer exposure times required.

Darkroom Organisation

Light-sensitive materials must be handled in special illumination to which they are reasonably insensitive. Hence enlarging requires a darkroom from which daylight can be completely excluded when necessary. On the other hand a darkroom is still a workroom and needs organising accordingly. The degree to which this is possible depends on the one hand on the space available and on the other on whether the darkroom facilities have to be temporary (mostly at home in the case of the amateur) or permanent.

In either event the darkroom must afford sufficient space to work in comfort. It also requires adequate ventilation to permit even a prolonged spell of work without discomfort or harm. Photographic materials are as sensitive to bad conditions – especially fumes, damp etc. – as the human organism. For that reason for instance the cellar of a house is one of the less desirable locations for a darkroom, unless it can be kept completely dry, well heated and ventilated.

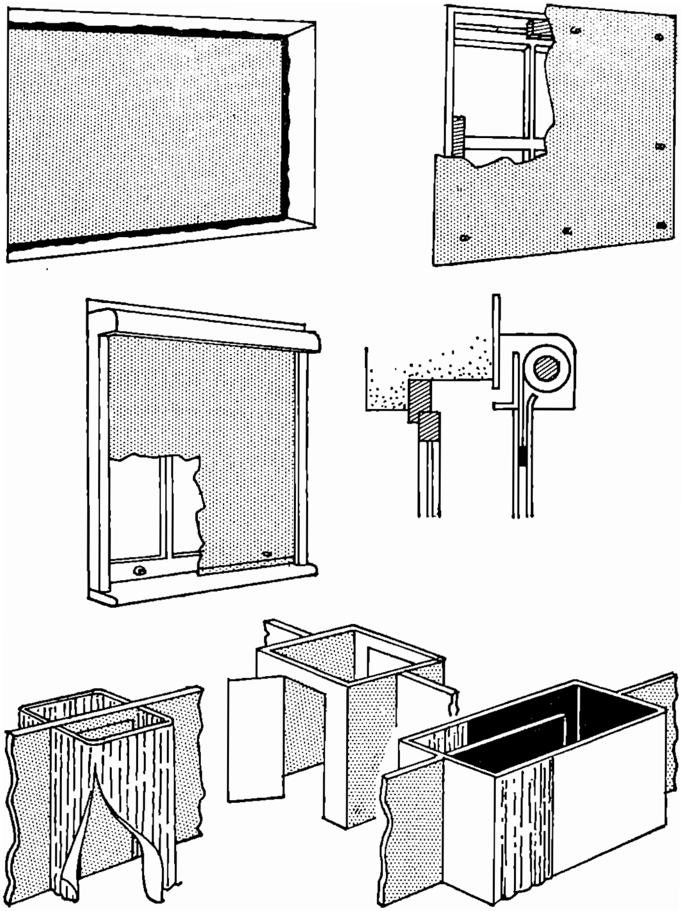
On the other hand, if these conditions can be ensured, a cellar has useful advantages. It rarely needs special darkening and it is least exposed to vibration from human traffic inside the building and road traffic outside.

DARKENING THE ROOM

For a permanent darkroom this rarely poses difficult problems. In a building constructed to house a professional or industrial photographic laboratory, the darkrooms are of course designed without windows – but with adequate ventilation. If a room with windows has to be converted in an existing house, it is a fairly easy matter to board up or even wall up the window permanently.

Blacking out a window becomes more of a problem in a room required for normal use (bathroom, bedroom etc.) when not occupied for photographic purposes.

There is a fairly wide choice of methods for dealing with a window in such a way that it can easily be opened again



Top: To black-out a well-recessed window (*left*) an opaque board edged with black felt may be pushed into the recess. Alternatively, a frame pushed into the window opening (*right*) can be covered with an overlapping opaque board.

Centre: A roller blind running in slots at either side of the window is convenient for quick darkening.

Bottom: Darkroom entrances. Simplest is a single door with heavy light-tight curtains on either side (*left*). A two-door arrangement (*centre*) provides a more effective light block; the labyrinth (*right*) is more convenient as it needs no doors. Its inside walls should be black.

when required. If the window is small, the simplest arrangement consists of a wooden frame which fits snugly into the window opening. The frame is filled with some opaque material such as plywood, hardboard or even light-proof fabrics. In the last case additional bracing may be required for rigidity. The frame must be made fairly precisely to measure, and a heavy dark cloth or felt lining around the edges will ensure easy fitting and efficient light trapping.

Where the window is fairly large, a more practical arrangement is a roller blind of opaque fabric, running in slots at the side of the window to form an effective light seal. These slots should be at least 2 inches deep, as narrow as possible, and painted matt black inside. Spring roller blinds are easily obtainable and are built into a partly enclosed cover at the top of the window frame. This set-up can be sufficiently unobtrusive, with the blind rolled up, to remain permanently in place.

Heavy curtains over ordinary windows are often adequate at night, where they may only have to keep out street lighting. They rarely keep out bright daylight, which limits enlarging activities to the hours of darkness – very short in the summer.

LIGHT-TIGHT ENTRANCES

The door to the room must be equally light-tight to avoid light leakage around or underneath the door itself. With older doors draught excluders often help. Alternatively – where space allows – a heavy curtain fixed to the door and overlapping it on the top and sides provides useful shielding.

For the busier professional darkroom where there is much movement of personnel, the entrance should be some form of light trap. The simplest way is to build a light-tight space into which the door can open, and hang a heavy light-tight curtain in front of it.

For large establishments an arrangement with double doors and more space between them is necessary, or a light-tight labyrinth may be used which makes doors unnecessary (page 205).

WALLS AND FLOOR

In temporarily converted darkrooms the walls and floor obviously have to be taken as they are. A recommendation

even for the most makeshift arrangement is to avoid rooms with carpeted floors. Not only is there the obvious risk of spilling solutions, but carpets also harbour dust which gets stirred up with every step – to settle on the optical surfaces of the enlarger.

In a permanent darkroom the walls should preferably be painted with a washable paint – semi-glossy oil paint is ideal. The walls are best light coloured, for instance pale grey or yellow. The ceiling and, if desired, the upper part of the walls, can be finished in white. This helps particularly when indirect safelighting is used (page 212). Dark painted walls are unnecessary; as even the whitest wall can only reflect light which falls on it, it cannot fog photographic materials if the darkroom illumination itself is safe.

The only exception to this is the wall behind the enlarger. This should be black for about 2 feet above the level of the baseboard, and over a stretch at least as wide as the baseboard. For there a light wall could throw back white light reflected from the printing paper during the enlarging exposure, and so degrade the image.

The area of the wall behind the wet bench where processing takes place, and also behind sinks, needs a top coat of glossy oil paint for additional protection against splashes. Alternatively that wall area can be covered with plastic sheeting. In professional darkrooms constructed as such it is best to tile the wall up to a height of about 1·5 m or 5 feet all round the processing areas.

In busy darkrooms the floor calls for special consideration. It should be protected against moisture and chemical action. The best materials are tiles, asphalt or a special chemical-resistant concrete coating. These are expensive, and cannot be laid everywhere. The next best is heavy gauge vinyl plastic sheeting – laid with the minimum of joins. Good quality linoleum, kept clean and well waxed, is also suitable. This can be underlaid with bitumen paper as an extra precaution against liquids getting through and damaging the actual floor.

If the floor covering can be brought up to the wall to a height of about 6 inches, the floor is easier to keep clean, with no risk of chemical-charged solutions seeping into gaps between the floor and the wall. This treatment is feasible with asphalt and also with vinyl sheet floor coverings. In the

latter case however corners must be made watertight with additional sealing.

VENTILATION

Every darkroom needs adequate ventilation. The means used naturally depend on its size and the volume of work done in it.

In a room of normal size which is reasonably well-ventilated when in ordinary use (i.e. not as a darkroom), two openings – one at ground level and one at ceiling level – should provide adequate ventilation. They must naturally be light-tight, but this is not difficult to arrange. The overall size of the openings should be about 6×30 inches.

The light traps are formed by thin boards providing a double-angle channel which effectively prevents any direct light penetrating. Each light trap must be painted matt black over the whole of its interior. The two wings of the light trap can be set about 7–8 cm apart.

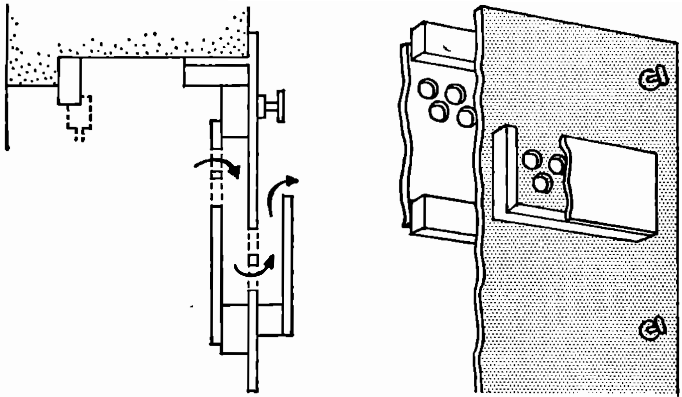
For professional darkrooms – especially small ones – a ventilation fan is usually the best arrangement. This should be mounted near the top of the wall or set in a boarded-up window. The fan may need light trapping to prevent light from getting in.

Normally a professional darkroom should provide at least 12 m^3 (400 cubic feet) of air for each person working in it. For a single operator this is a room about $2 \times 2{\cdot}5$ m, with a $2{\cdot}5$ m ceiling (or $6\frac{1}{2} \times 8 \times 8\frac{1}{2}$ feet). The fan should be able to change the air about 8 to 10 times an hour.

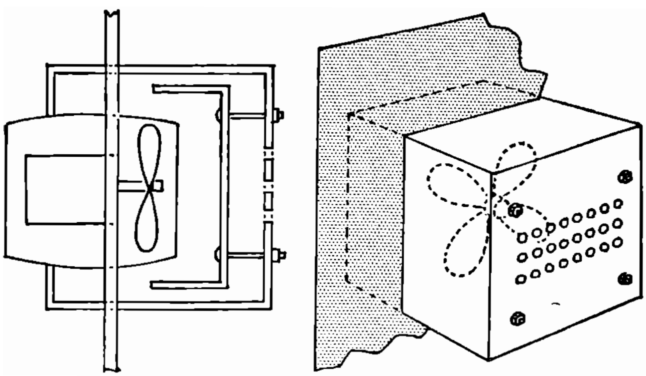
HEATING

To keep a darkroom warm, central heating is of course ideal. Next best are oil-filled electric radiators, preferably with thermostatic temperature control. Electric convection heaters are less satisfactory, because their elements are hot enough to scorch the dust in the air going through. This dust then tends to settle not only on nearby walls, but also on optical or other components of the enlarger. The same objection, plus fire risk, is valid against incandescent electric radiators. The light from the glowing element however is reasonably safe for bromide enlarging papers, though not for panchromatic or colour papers.

Paraffin and gas heaters should never be used in a dark-



Where the room is darkened by boards or screens over a window, these can incorporate light-trapped ventilation holes near the top and the bottom of the screen. If the window is left partly open, air can then flow in and out of the room.



Permanent darkrooms, especially small ones, require more efficient ventilation. An extractor fan is ideal, and fairly easy to make light-tight. It can be built into a door or wall.

room. Not only do they use up oxygen of the air, but their fumes may impair the keeping quality of sensitive materials.

Electric heaters with accessible elements (especially the glowing radiator type) are unsafe also because of the risk of electric shock. If the heater has been incorrectly wired to its mains plug, the danger of shock may be present whenever the heater is plugged in, even though the element may be switched off.

In any darkroom it is best to have the room at its working temperature for some time before starting to work, so that solutions and processing equipment have reached this temperature.

In hot weather and especially in hot climates the darkroom may need cooling instead of heating. Refrigeration units used for this purpose rarely raise any special problems. In professional and industrial darkrooms the most convenient way of ensuring both adequate ventilation and correct temperatures is an air-conditioning system.

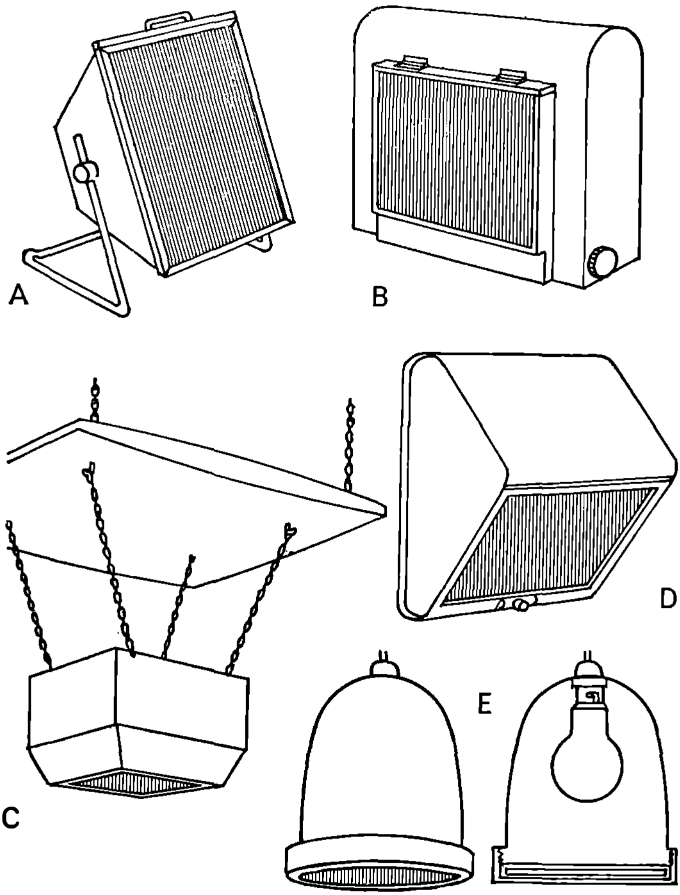
DARKROOM ILLUMINATION

The aim of efficient darkroom illumination is to provide the maximum amount of light compatible with the safe handling of sensitised material. The safety of the lighting depends in the first place on its colour and secondly on its intensity. The latter is determined by the power of the light bulb used in the darkroom lamp and its distance from the sensitive emulsions handled.

The size of the light source however governs the amount of light spread throughout the darkroom and hence the general lighting level. The higher this is, provided the light intensity reaching the emulsions remains below the safety level, the more convenient the darkroom is to work in. For this reason large safelight units – and a number of them in bigger darkrooms – are greatly preferable to small ones. A safelight area of about 160 square cm should be regarded as the minimum even in a small makeshift darkroom; anything less means that the lamp has to be brought so near to the working area for an adequate lighting level, that it is no longer safe. The various types of coloured light globe and light bulb covers are thus not the best solution to efficient darkroom lighting.

Darkroom lamps usually consist of a box containing the

DARKROOM LAMPS



Standard lamps for bench use (A) take interchangeable safelight filters up to 5 × 7 or 8 × 10 inches and a 15 or 25 watt bulb. Lamps for shelf and wall mounting (B) and (D) are substantially similar. A ceiling lamp (C) with two safelight filters 8 × 10 inches or larger gives both direct illumination downwards and indirect illumination by reflection from the ceiling or a white reflector. Circular bell or beehive-type lamps (E) take 13 cm or 5½ inch circular filters and can be suspended in various ways for local bench illumination.

light bulb, with a window to take a safelight filter of the appropriate colour. The most popular safelight sizes are 13 cm ($5\frac{1}{2}$ inch) circular, 13 × 18, 20 × 25 and 25 × 30 cm or 5 × 7, 8 × 10 and 10 × 12 inches.

Lamps of the two smaller sizes are generally employed for direct lighting of the work bench. For this purpose the lamp contains a 15 or 25 watt bulb; it should be at least 4 feet from the enlarging paper being handled. The larger safelights can be used either for direct illumination or for general reflected lighting with a 25 or 40 watt bulb. Here the lamp is suspended to shine up at the white painted ceiling, so that the latter reflects the light over the whole darkroom. If the ceiling is too high, a white reflecting panel may be suspended above the darkroom lamp. The recommended minimum distance of sensitive materials from the reflecting surface is in this case about 2 m or 7 feet.

SAFELIGHT FILTERS

Photographic manufacturers issue their own recommendations for the safelight filters to be used with various materials.

For normal bromide papers the required safelight is usually orange or olive green. Certain variable contrast and high-speed document papers of orthochromatic sensitivity may require a deep orange or light red safelight. Contact papers can be handled in a yellow safelight.

Usually the characteristics of corresponding papers of different manufacturers are sufficiently similar to permit the use of, for instance, a bromide paper safelight of one make with normal bromide papers of most other makes. For special materials, and in particular colour papers, it is best to use the safelight filter recommended by the maker of that paper. The same applies to panchromatic enlarging papers.

A special type of safelight suitable for large printing darkrooms is a sodium lamp. This provides a very high level of illumination and is most suitable for general lighting by reflection from the ceiling. The light is safe for bromide and contact papers; the former must however be handled at least 10 feet away from the lamp. In smaller darkrooms (less than about 6 × 9 m or 20 × 30 feet large) a neutral density filter has to be fitted over the sodium lamp to cut down its light intensity. Sodium lamps also require certain electrical accessories (transformer, choke).

DARKROOM LAYOUT

The procedures involved in enlarging cover four types of operation which take place in the following order:

1. Dry work requiring safelight illumination (handling the paper, exposure);
2. Wet operations requiring safelighting (processing);
3. Wet operations which can take place in white light (washing, drying, glazing); and
4. Dry operations in white light (trimming, spotting etc.).

The darkroom must obviously accommodate operations (1) and (2). They must however be kept separate in the layout of the room, whatever its size. So the darkroom needs a dry corner or bench for handling the papers and negatives and to accommodate the enlarger. A wet bench takes the processing dishes or other processing equipment.

Running water and drainage facilities – for instance a sink – are desirable for the wet operations taking place in the dark, but not absolutely essential. A waterproof lead or plastic lined trough, with a wooden rack on which dishes can rest, is also adequate.

Wet operations in normal lighting such as print washing, but also the making up of solutions, can take place in a bathroom or any other place fitted with a basin or sink and running water. The final dry operations need have no connection with darkroom facilities at all.

In professional processing departments on the other hand the four procedures (1) to (4) above are best distributed in separate rooms, though (1) and (2) can still be together. At the end of the fixing stage the prints can then be passed from the darkroom to the light room through a suitable hatch (page 223).

In the light of this we can now consider various typical darkroom arrangements, both improvised and permanent.

IMPROVISED HOME DARKROOMS

Traditionally the bathroom is regarded as a suitable location for makeshift darkroom operations. Its only merit for this purpose is the availability of running water; from every other point of view it has considerable disadvantages. Apart from the inconvenience it causes in a household to occupy the bathroom for hours on end, the damp and steamy

atmosphere in normal use makes it highly undesirable for the storage of photographic equipment or materials. These therefore have to be taken into the bathroom and set up there before an enlarging session. In modern houses or flats neither the layout nor the size of a bathroom are very suitable for conversion.

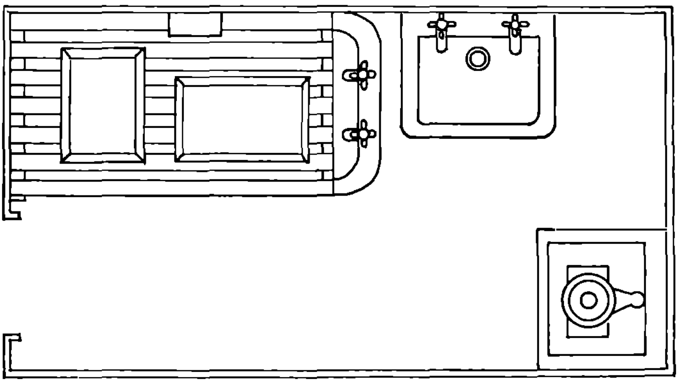
Also, present-day building regulations (in Britain) prohibit the fitting of electric outlets – for connecting the enlarger, darkroom lamp and possibly processing machine – in a bathroom. These would therefore have to be brought in from outside by a power cable and distribution box, the cable being led through a channel in one corner of the door. The other end can be plugged into a suitable power point outside the bathroom.

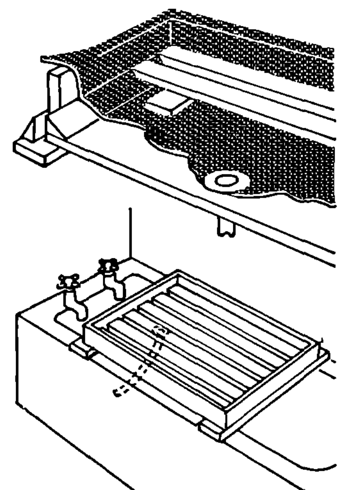
The wet bench in such an arrangement can be a wooden rack placed over the bath itself. A large waterproof tray to hold the rack and fitted with a drain and hose (to lead into the overflow of the bath itself) will reduce the risk of stains in the bath through solution splashes. The rack takes the processing dishes or roller processing machine.

The dry bench for the enlarger usually has to be a temporary fitment (unless a solid flat topped cupboard is available in the room) but it should nevertheless be rigid. The dry bench must have space alongside the baseboard for handling papers, loading negatives into the negative carrier etc. Boxes of paper are best kept on a separate shelf underneath. Other darkroom accessories – timer, enlarging exposure meter etc. on the dry side, and measures, bottles etc. on the wet side – are best kept on a shelf above the working area.

All electrical equipment used in the bathroom must be efficiently earthed.

The same arrangement is suitable when converting a small bedroom for an enlarging session. Apart from darkening the room (page 204) this only requires two tables for the wet and dry bench respectively. These are best kept along separate walls of the room, possibly with an anti-splash division if necessary. The wet bench should in this case be a large water-proof tray on top of its table; if the room is carpeted, newspaper or a sheet of plastic underfoot will protect the carpet. This tray then holds the developing dishes or the roller processing unit (page 232).

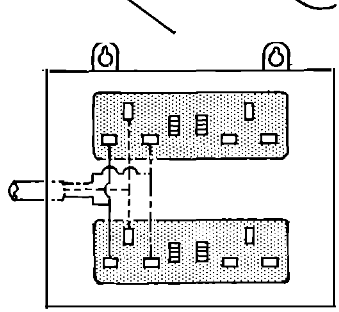




Above: A bathroom can make an improvised darkroom, but is not always convenient. Dishes may be supported on planking over the bath; the enlarger needs a suitable table.

Right: A wooden framework covered with lead sheeting and a drain can form a makeshift sink; this is also desirable if dishes are supported over the bath, to prevent stains in the bath itself. The draining tube goes directly to the plughole of the bath.

Bottom right: The electric supply in the bathroom may have to be brought in from an outside power point. There a simple plug-in distribution board is useful.



THE CUPBOARD DARKROOM

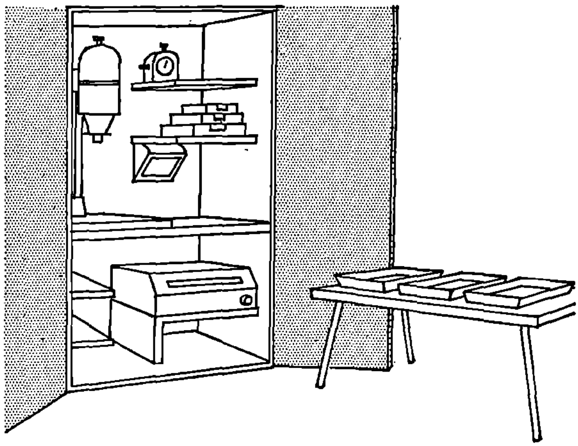
This is an answer to the problem of permanent storage of darkroom equipment in a small home. It uses a wardrobe, or cupboard built into a wall recess or similar place, large enough to hold the equipment ready for use (i.e. not dispersed wherever room can be found for it) but not large enough to work in. The room containing the cupboard becomes – on darkening – the darkroom proper, but the equipment is not removed from the cupboard for use. The latter contains a permanent working layout and is simply closed but not removed from the room when not in use.

The cupboard darkroom is ideal for working with roller processing machines (and papers suitable for them – page 78), since the roller processor takes up less bench space than a set of dishes, and can in fact be accommodated on a shelf underneath the enlarger.

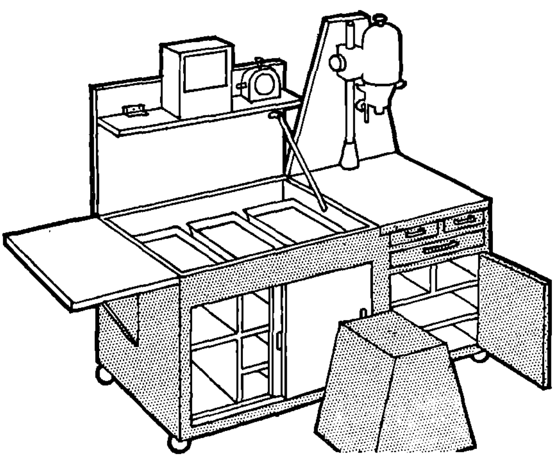
The main shelf in the cupboard at a convenient working height becomes the dry bench to hold the enlarger itself and to afford some working space alongside. Shelves above this working space may hold the boxes of enlarging paper and various accessories (timer, masking frame etc.). The darkroom lamp – and also a white light – possibly connected to the darkroom lamp via a two-way switch – is fixed to the inside of the cupboard door. Shelves below the dry bench house the roller processor or developing dishes, also the solutions, chemical stocks etc. – all the "wet" equipment.

The operator sits or stands outside the cupboard; he has everything at hand, while benefiting from the larger space of air of the room in which the cupboard is placed. (This is also the main distinction between this type of cupboard darkroom and the converted stair cupboard which houses the photographer and its equipment. Since that has to be light-tight, it needs good ventilation – at least by a fan – to remain bearable for more than very short work periods.)

If the prints have to be processed in dishes, these are best set up on a table serving as wet bench alongside the cupboard. This cupboard should carry a large waterproof tray to hold the dishes (see also page 217). Splash protection underfoot, for instance in the form of a waterproof sheet to protect the floor (or carpet) is desirable. The supporting tray can even form the top of a folding table to be stored inside the darkroom cupboard when not in use. If the cup-



The cupboard darkroom contains a work bench and shelves for enlarger and equipment. It is opened up for use in a darkened living room. Prints may be processed in a roller processor below the work bench, or in dishes on a separate folding table.



The darkroom trolley consists of an enlarger table and sink unit for dishes. When not in use the unit folds up (the stool becomes the enlarger cover) and can be wheeled into a convenient corner. A roller processor may be fitted below the enlarger, in which case the processing section becomes unnecessary. The unit is again used in a darkened living room.

board is large enough, the dishes could even be accommodated – on a waterproof catchment tray – on a shelf below the dry bench.

The darkroom lamp on the cupboard door has to be positioned to throw enough light on the processing dishes without being too near to them. Also built into the cupboard is a distribution box with outlets for the enlarger, darkroom lamp, processing machine etc. The cable from this is rolled up in the cupboard when not in use, and should be long enough to reach the nearest power point in the room.

After a processing session all "wet" equipment (dishes etc.) is thoroughly dried after washing, before being stored in the cupboard. The same applies to the catchment tray for the wet bench or for the solution trays of the roller processor. The closed cupboard does not afford sufficient air circulation for these items to dry on their own. Neither sensitised materials nor camera equipment should be stored inside such a darkroom cupboard.

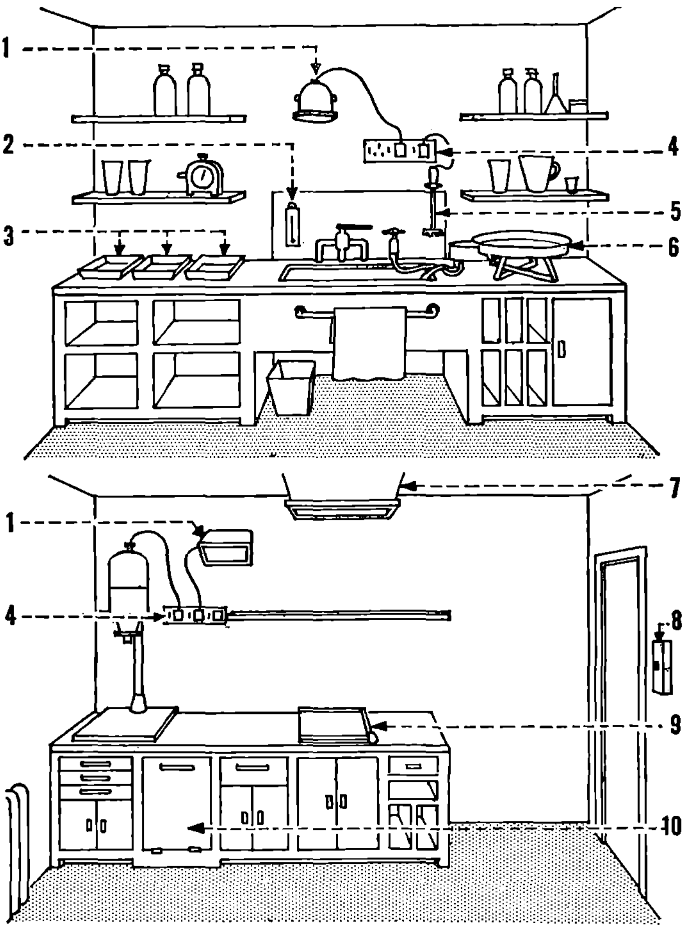
Cupboard or "wardrobe" darkrooms of this kind are also produced commercially. Refinements there may include a light-tight curtain which encloses the cupboard and the photographer sitting in front of it, making the unit usable even in daylight, but requiring efficient ventilation.

THE DARKROOM TROLLEY

This is a variation of the darkroom cupboard idea and is a specially designed piece of furniture, partly on wheels, to house all the enlarging and processing equipment. The top of the unit carries the enlarger which is covered by a hood when not in use. The space alongside serves as dry bench; a folding flap next to it – possibly with a splash division – can hold processing dishes or a processor. The unit can stand in a corner of the room, being wheeled into a convenient working position when in use. The room will need separate darkroom illumination, such as a portable lamp set up above the work bench.

PERMANENT DARKROOMS

The requirements of the amateur photographer establishing a permanent darkroom in his home and of the professional adapting existing premises for photographic processing are similar in many respects, but different in one or two others:



Wet bench (*top*) and dry bench (*bottom*) of a medium size amateur or small professional permanent darkroom. 1, wall safelights for local illumination; 2, thermometer; 3, dishes; 4, power points (well above bench level, especially on wet bench); 5, immersion heater; 6, print washer; 7, ceiling light for general illumination; 8, boxed-in safelight and white light switches; 9, print trimmer; 10, light-tight paper cabinet. Dishes, bottles and other equipment can be kept in the storage space below the benches.

(1) In an amateur darkroom running water is desirable, but not essential. Thus it is perfectly possible to carry a jugful of water into the darkroom to dilute processing solutions if necessary (stock solutions should be made up beforehand) and to fill a dish to keep prints soaking after their final processing bath. Washing of the prints (and – after an enlarging session – of the processing dishes etc.) can take place in the bathroom or the kitchen sink, and spent processing solutions emptied into another jug for pouring away afterwards.

Since a professional darkroom is generally in constant use, it is not convenient there to carry out part of the operations in a bathroom or other temporary location. So here running water does become essential.

(2) Even if plumbing is available in the room, it is usually necessary to fit suitable sinks to hold developing dishes etc.

Drains and waste pipes should be easily accessible in this case for the removal of blockages caused by sediments in waste solutions or by paper.

(3) For intermittent amateur processing a domestic drainage system is adequate for the disposal of spent solutions. A professional photographic laboratory – particularly a larger one – needs special drainage and waste disposal facilities. In large establishments it is generally also worth-while to recover silver from spent fixing baths.

(4) Similarly, the water supply for an amateur darkroom need not be very abundant. For professional work a greater water flow may be necessary and hot as well as cold water is desirable. The use of water in such a darkroom may require special arrangements with the local Water Board as it is usually classified as a trade or industrial supply.

(5) Working conditions in a professional darkroom may under certain circumstances be subject to official inspection under the Factory Acts. The features usually insisted on – adequate ventilation, safety of electric wiring, earthing, insulation etc. – are however equally desirable for an amateur darkroom. When installing wiring it is advisable to obtain the advice of a qualified electrician or the local Electricity Board.

(6) Amateur darkrooms are often planned for the "dark" operations only, but may include – if space is available –

facilities for washing, drying, glazing etc. of prints. Frequently the equipment for this purpose has to be stored in the darkroom anyway, because there is nowhere else. Professional processing departments are generally planned to provide separate rooms for these routine operations, especially as they are frequently carried out by staff other than the darkroom operator. Where these activities go on simultaneously instead of in succession (as with a one-man set-up) separate working space for them is essential.

(7) Similarly, for want of a better place, the amateur darkroom serves also for storing papers (as well as films) and chemicals, and for making up solutions. Professional establishments nearly always have separate rooms for chemical storage and solution preparation on the one hand and for materials storage on the other.

Handling solid chemicals in the darkroom is undesirable because of the chemical dust which is liable to settle on papers during handling and to cause spots. If no separate chemicals room can be set up, it is advisable to buy all chemicals in the form of concentrated stock solutions. This may be a little more expensive; it is however not only safer but far more convenient.

Sensitised materials are best stored outside the darkroom in any case, away from possible dampness and contamination.

LAYOUT PRINCIPLES

These are largely the same for permanent amateur and professional darkrooms. The exact arrangement will of course depend on the space available and other individual conditions.

The special division between wet and dry manipulations is again a first requirement. A useful arrangement is to have the wet and dry benches along opposite walls of the room, so that the operator only needs to turn round to place an exposed sheet of paper in the developer or processing machine. If the dry and wet benches are along adjacent walls, an anti-splash division is again advisable. In this case the enlarger should be nearest to the processing bench, with the dry handling bench farthest away from all solutions.

The dry and wet working areas should have their own local darkroom lighting. If enlarging exposure meter units

are used, it must be possible to switch off all safelights. A white light, with a shuttered switch protected against accidental operation, is useful for judging test strips or prints.

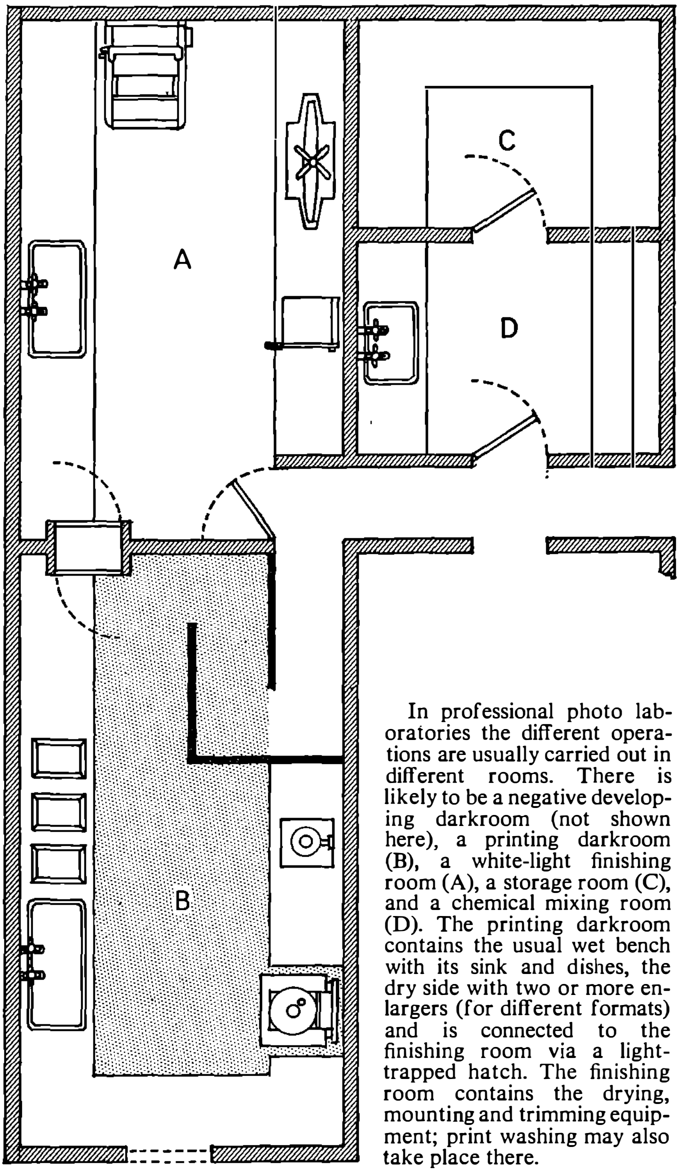
The position of the wet bench will, where a sink is used, depend on the location of the plumbing connections and especially of waste pipes. If conditions allow, the wet bench should include also a flat and more or less dry working surface to take a dish heater or other equipment associated with processing.

The enlarger is best placed on a separate solid bench or table located near an outside wall of the house rather than an internal dividing wall. There it is least affected by vibration, especially from people walking about inside the house. Where feasible, a wall-mounted enlarger column (page 166) affords the greatest steadiness.

The darkroom lamp for general illumination will usually be wired through the lighting circuit of the room to a switch near the door. A second lamp for white light may be similarly wired to another switch. Other electrical equipment – the enlarger, auxiliary equipment, roller processor, dish and solution heaters, bench safelight etc. are best connected to outlet sockets let into the wall. These should be of the three-pin earthed type (except possibly for the bench lamps). The outlets for the dry section (enlarger etc.) are best set about a foot or so above the level of the working surface: those for the wet section should be at least 3 feet above bench level to be well clear of splashes. These outlets should be shuttered for additional safety.

Fused plugs for all equipment are ideal; they simplify fuse changing when necessary. Fuse ratings should be selected according to the current taken up by each item of equipment.

The space underneath the wet bench can serve for the storage of dishes, solution bottles, film tanks and hangers (unless a separate negative processing room is available, the darkroom will also serve for film development), and other bulky processing accessories. The space below the dry bench might hold the various enlarging accessories and possibly incorporate a light-tight paper cabinet. Shelves above the benches can serve for storing smaller and more frequently used items – measures, funnels, thermometer etc. on the processing side, and a timer, spare negative masks



In professional photo laboratories the different operations are usually carried out in different rooms. There is likely to be a negative developing darkroom (not shown here), a printing darkroom (B), a white-light finishing room (A), a storage room (C), and a chemical mixing room (D). The printing darkroom contains the usual wet bench with its sink and dishes, the dry side with two or more enlargers (for different formats) and is connected to the finishing room via a light-trapped hatch. The finishing room contains the drying, mounting and trimming equipment; print washing may also take place there.

etc. above the dry bench. Wall cupboards with sliding doors have the advantage of protecting such items against dust.

LARGER COMMERCIAL DARKROOMS

In specially planned photographic departments of bigger organisations the different functions of printing are, as already mentioned, frequently allocated to different rooms. Thus the darkroom proper contains only the equipment actually used for exposing and developing the prints (usually there are separate negative developing rooms) and the prints may be passed through a light-tight hatch into a light room for the final stages of washing, drying etc.

Often the printing room contains several work places, each with its own enlarger, for a number of operators. These may be associated with one or more processing benches, again separately staffed to permit the maximum output of work. The work stations are not necessarily identical; thus one operator may enlarge only miniature negatives, another deal with big formats and so on.

The processing section is generally more elaborate, utilising sometimes automatic and continuous processors for black-and-white as well as colour materials. The two may even be handled in different darkrooms.

The work stations are of course individually illuminated and may be screened off from each other when different operators work with materials of different colour sensitivity.

The layout of such processing departments will necessarily vary appreciably according to individual requirements.

COLOUR DARKROOMS

Apart from the special safelighting and suitable colour enlargers, the printing side of a darkroom for colour work usually does not differ greatly from the arrangement for black-and-white work. Processing however requires more extensive facilities for processing tank sets (professional processing of colour prints is hardly ever carried out in dishes) together with ancillary equipment for temperature control, agitation etc.

Since consistent quality in processing colour papers also depends on regular solution replacement according to fairly precise schedules, facilities for easy draining and refilling of solution tanks are desirable. The most efficient

arrangements involve automatic replenishment from storage containers. For manual replenishment and replacement a shelf above the processing bench may carry storage bottles of each solution, fitted with an outflow near the bottom and a tap or similar device for drawing off solutions without handling the storage bottles themselves.

In highly organised processing laboratories – for black-and-white as well as for colour work – constantly used solutions may be piped to plastic taps or feed tubes in the darkroom from storage containers outside.

THE MOBILE DARKROOM

Certain organisations requiring photographic documentation on location (for example expeditions, also armed forces in the field) use mobile darkrooms built into lorries or trailers. Such arrangements may also be suitable for professional photographers specialising in work where a delay in processing and printing – occasioned by returning exposed material to a permanent base darkroom – is not acceptable.

The equipment of a darkroom trailer or van is in principle similar to that of a permanent home darkroom. The main principles in layout are the condensation of facilities into the minimum possible space. Enlarging and processing equipment is therefore designed for the specific purpose and material being used, rather than for all-round versatility. Mobile darkrooms however frequently have to process films as well as prints.

Plumbing arrangements are necessarily designed to use the minimum of water; this may be stored in tanks built into the vehicle. The enlarger and other electrical equipment usually has to run off low voltage batteries, though in some cases connection of the mobile darkroom to an external mains supply is possible.

Less sophisticated mobile darkrooms may take the form of darkroom tents used on expeditions.

Darkroom Equipment

Apart from the enlarger and its accessories (masking frames, exposure measuring gear etc. – see page 255, 263) the most important apparatus and utensils in a printing darkroom are:

(1) *Dishes or tanks* for the developer, stock bath and fixing bath. Two dishes may be wanted for fixing, using a two bath system (page 347). Additional dishes are useful for holding prints soaking after they have emerged from the fixer if no running water is available in the darkroom.

More dishes may be required for colour processing if additional solutions are involved.

If a roller processing machine is used (page 232) it replaces the dishes. Drum processors for colour prints (page 369) require their own special dishes or solution tanks.

(2) *Forceps* are very desirable for handling the prints while in the solutions when processing prints in dishes. Fingers should *not* be used for this purpose, to avoid the risk of stains and marks through handling unexposed or exposed papers with fingers contaminated by the processing solutions.

Separate forceps must be used for the developer on the one hand, and the stop bath and fixer on the other. These should be readily distinguishable by colour and/or shape to prevent accidental contamination of the solutions with each other. (A few drops of fixer in the stop bath and vice versa do no harm; stop bath or fixer in the developer ruin the latter.) If large prints are handled, two pairs of forceps may be needed in each dish.

The fixing dish should also have a print paddle which enables the prints to be moved about and separated.

The fixing bath should be placed at some distance from the developing tank or dish to prevent any possibility of contamination of one bath by the other.

(3) *Washing arrangements.* It is not essential to have these installed in the actual darkroom (page 220). At home run-

ning water flowing into a sufficiently large sink or the bath is adequate, provided the water is changed at a reasonable rate. Print washers of various types (page 353) carry out this operation more efficiently.

(4) *Smaller but useful items* are a thermometer, large and small measures for making up the working developer for stock solutions, and funnels for pouring solutions into bottles and for filtering.

Thermometers should be designed for use in the dish or tank employed. Accurate temperature control is important in colour processing. With tank installations, dial thermometers with a sensing probe immersed in the tank are often more convenient.

Measures are best graduated in cubic centimetres or millilitres – this makes the calculation of dilutions easier. A large measure should hold 500 or 1000 ml and can be made of polyethylene plastic. The small measure should hold 25 to 50 ml; here glass (and a cylindrical shape) is preferable for accuracy. A dropping tube marked in fractions of a c.cm. is handy for measuring out very small volumes of solution additive.

(5) *A plastic waste bin*, a rag for wiping up spilt solutions (which should always be done immediately) and a towel are further desirable items in any darkroom.

(6) *Useful are also timers* – to time exposures on the one hand and processing periods on the other – and a paper storage cabinet. The paper cabinet is something of a luxury in an amateur darkroom, but saves a great deal of time by eliminating the constant unpacking and repacking of envelopes or boxes of enlarging paper.

The cabinet must be light-tight and should contain several compartments to accommodate papers of different types and contrast grades – the compartments being clearly labelled. The cabinet should also have a safety lock to prevent inadvertent opening while white light is turned on in the darkroom.

MATERIALS FOR DISHES, TANKS, ETC.

Dishes and other containers for photographic solutions are obtainable in a variety of materials, the most popular ones being plastics, hard rubber, enamelled steel, stainless steel, stoneware, well glazed porcelain and glass.

In addition, where tanks or vessels of large size are concerned, wood is a useful material, if impregnated with wax or coated with water-proof and chemical-proof material such as rubber or metal, rubberised cloth, asphalt or plastic.

Among plastics, *polyvinyl chloride* (PVC) is useful for dishes, trays in roller processors, and for pipelines. It is reasonably, but not fully, rigid.

Polystyrene is popular – both in transparent and coloured forms – for processing dishes. In its favour is its great mechanical strength; it is however brittle and does not stand up to strong acid.

Perspex, also transparent, is one of the most resistant as well as strongest plastics and is used for processing dishes and trays.

Polyethylene is useful for piping and small utensils such as measures, funnels etc. Its low rigidity does not make it suitable for big dishes and tanks. Polyethylene is attacked by strong oxidising agents (for example bleaching solutions used in colour processing).

Bakelite is one of the oldest plastics and finds use in tanks and various fittings. Owing to its low mechanical strength and brittleness it has today largely been replaced by PVC and polystyrene.

Nylon is very strong and resistant (except against strong acids) but also expensive. Its main use is in gears and other moving parts which have to operate submerged in solutions – for instance in roller processors.

Laminated Resin-bonded Materials with fabric, paper or asbestos base are also used for moving parts operating in solutions. In sheet form, laminated plastics also make an excellent covering for darkroom benches, and are available in a number of colours and finishes (including imitation wood grains) under various trade names.

Self-adhesive Polyvinyl Foil – available in sheet form in numerous colours and patterns – makes a useful splash resistant covering for walls and for lining shelves and cupboards. The thicker grades can also be used for covering work benches.

This material has however no mechanical strength and does not stand up either to prolonged wetting or heat, which destroy adhesion to the support.

OTHER MATERIALS

Hard Rubber is an excellent material for tanks of all photographic solutions used at normal temperatures. Usually this material is however made with an asphalt mixture or with mineral filler. The rubber material must not contain any free sulphur.

Dishes or Tanks of Enamelled Ware find very general use because of their unbreakability. But they are not ideal, for the enamel is rather easily cracked or damaged. Thus they soon become unusable because the metal under the enamel is rapidly corroded once the enamel itself has chipped. Moreover strongly alkaline solutions, although rarely used in positive processing, can and do attack enamel in time.

Stainless Steel is very serviceable and durable for processing tanks, processor machine fittings and especially for sinks. Not all grades of stainless steel are however equally suitable; molybdenum stainless steels of low carbon content (less than 0·08 per cent) are generally the most resistant ones. Cheaper stainless steels are liable to plate out silver from exhausted fixing baths and may be attacked by bleaching solutions used in processing colour prints.

Plated Metals are rarely satisfactory because the plating is usually porous and galvanic action rapidly corrodes the base metal once the plating has become damaged. Galvanised iron can however be used for washing tanks (but little else).

Porcelain or Stoneware is suitable for large tanks and sinks. It must however be well-glazed and even then can give rise to trouble when, with use, the glaze begins to show tiny cracks or to craze, as it is called. Solutions find their way into the cracks and increase the trouble by crystallising in the cracks if the vessels are allowed to dry without careful cleaning. Moreover, the salts percolate into the unglazed porcelain or stoneware, and so cause contamination if the vessels are used for more than one purpose.

Reinforced Concrete faced with cement is satisfactory for large sinks or washing tanks. The surface must in this case be treated with asphalt paint or lined with $\frac{1}{8}$ inch thick sheet rubber or sheet lead.

Glass is a suitable material for almost all purposes, apart from the fact that it is brittle and easily broken.

Wood can be utilised in many ways, and is cheap and very

suitable for making large tanks, sinks or other large vessels. It can be impregnated with wax, coated by spraying with hard or soft rubber solutions or with self-curing liquid plastic. It can also be painted with asphalt paint, or, in the case of sinks, lined with lead sheeting. All these methods must protect the wood against becoming soaked with solutions – which leads to warping and rotting. Cypress and teak are among the most resistant woods and are least affected by occasional wetting.

Whatever method is used, the treatment should be carefully watched and renewed at the first sign of serious wear. In this way wood vessels will give years of service.

THE SIZE OF DISHES

A dish for developing should be about 2–3 cm larger each way than the biggest paper format to be developed. Too large a dish is wasteful as it requires a large quantity of developer – unless the volume of work is such that the developer has to be changed at fairly frequent intervals.

For fixing the dish can be larger than the paper, as it is customary to fix several prints simultaneously.

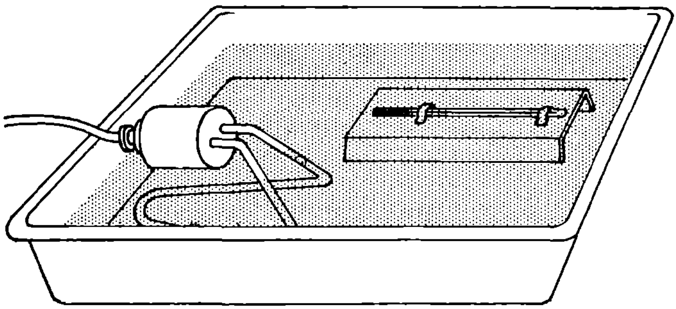
The dishes should however be reasonably deep to reduce the risk of spilling solution when the dish is rocked during development. About two inches is a useful depth, except for the very smallest dishes.

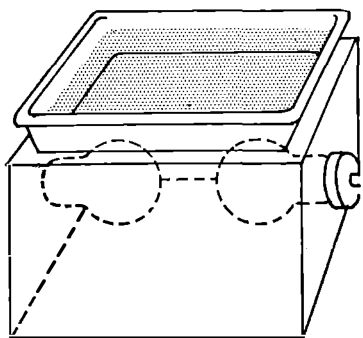
Dishes should also be rigid – again to permit rocking without distortion – and have a pouring lip. Internal ridges make it easier to pick up a print lying in the bottom of the dish.

TEMPERATURE CONTROL

In cold weather processing solutions act more slowly and some developers fail to act properly at all. The baths – especially the developer – should therefore be kept at the recommended temperature, usually 18°–20° C (65°–68° F).

There are various ways of maintaining the developer in a dish at the required working temperature. A simple, but cumbersome, way is to stand the developing dish in a larger dish of warm water. More convenient is a dish heater, in effect a heating plate warmed underneath by a low-power element. A heater of this kind can even be home-made, using a metal box with one or two 60 watt light bulbs in-

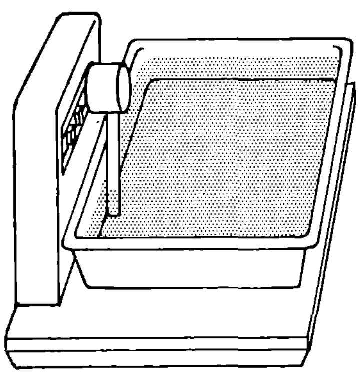




Above: An immersion heater is the quickest way of warming up solutions in a dish. A dish thermometer is desirable for temperature control.

Right: Failing a commercial dish heater, a simple unit can be home made by mounting a couple of 60 watt light bulbs inside a biscuit tin and standing the dish on top. The tin must be earthed.

Bottom right: Automatic dish heaters with thermostatic control may use a thermometer probe which dips into the solution and controls the heater element through a thermostat.



side. These are switched on as required, while checking the solution temperature in the dish placed on top of the box. The box must of course be light-tight, and should also be earthed for safety. Dish heaters of this kind are available commercially.

More elaborate instruments may incorporate a sensing thermometer, linked with a relay which automatically switches the heating element on and off to keep the temperature of the solution in the dish constant.

For rapid warming up of processing solutions, dish immersion heaters can be used. These need only be switched on for a few seconds at a time, and are employed in conjunction with regular temperature checks with a dish thermometer.

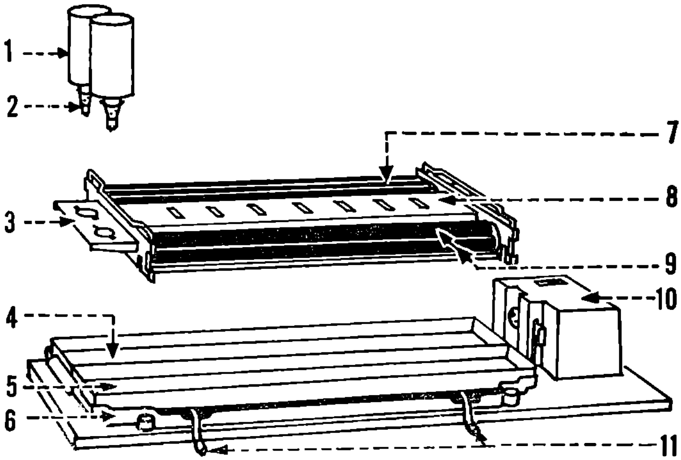
Stricter temperature control is essential when processing colour papers, and is achieved in tank processing sets with a thermostatically controlled water bath (page 370).

ROLLER PROCESSING MACHINES

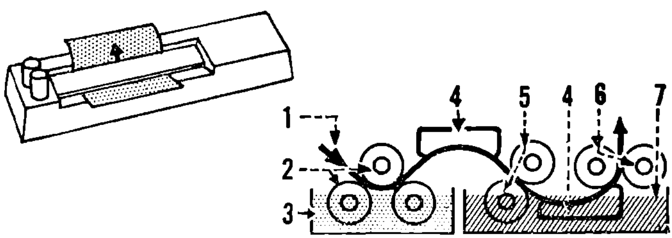
These are used with rapid processing papers which incorporate the developing agent in the emulsion (page 78). The processing machine consists of two oblong trays, sometimes carried inside a drip tray, with a roller unit dipping into the trays. The first tray carries the activator which starts the development as soon as it reaches the developing agent in the emulsion; development is complete within about 2–3 seconds. The second tray contains a stabilising solution which replaces the fixing stage in this process (see also page 348).

The rollers are motor driven, and the paper is fed into the machine emulsion downwards, between the processing rollers. The lower roller dips into the activator, and applies it to the print surface as the latter passes through. The paper is thus never immersed in the activator itself at all. The rollers continue to push the paper along a guided path into the stabiliser bath, and out again. As the paper leaves the stabiliser, another pair of rollers squeegees off surplus stabiliser solution, so that the print emerges in a damp but not wet condition and takes only a few minutes to dry completely. The passage of the paper through the processor takes about 10–15 seconds for a 20 × 25 cm sheet.

Commercial roller processing machines come in a number



The machine generally consists of a pair of trays for the activator and stabiliser, located on a base which also carries the motor. The latter drives the roller systems which apply the solutions to the paper surface and carry the paper through the processor. 1, Replenishing bottle; 2, automatic "chicken feed" valve; 3, bottle holder; 4, stabiliser tray; 5, activator tray; 6, drip tray; 7, squeegee rollers; 8, paper guides; 9, activator rollers; 10, motor, 11, draining tubes for the solution trays.



In use the processor is protected by a cover with the feed in and feed-out slots for the paper (*left*). The roller arrangement varies a little in different machines, but the one shown here (*right*) is fairly typical (Ilfoprint processor). 1, paper path; 2, activator application rollers; 3, activator; 4, paper guides; 5, stabiliser application rollers; 6, squeegee rollers; 7, stabiliser.

of sizes, for paper widths from 20 cm or 8 inches; processors for large-scale document copying machines can handle paper widths up to 1 metre (40 inches). The paper length is in theory unlimited; in practice processors for big print sizes need accurate tracking arrangements to ensure that the paper keeps running straight through the rollers over its whole length.

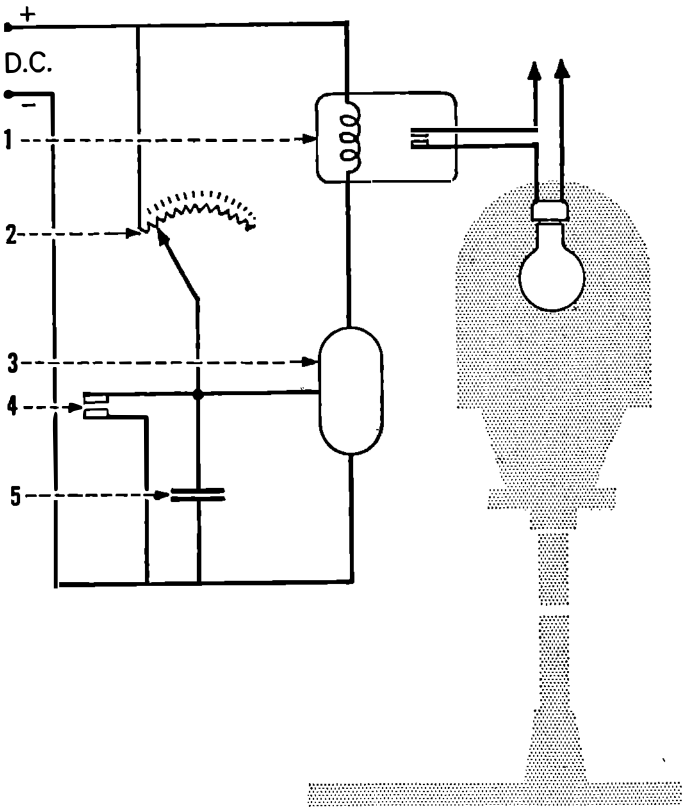
The most generally useful size for the professional and advanced amateur darkroom is a processor taking paper widths up to 40 cm or 15 inches. This can handle for instance 30×40 cm or 12×15 inch enlargements. The next bigger models take widths up to some 50 cm. Sometimes the roller processor is combined with a contact printing box for document copying (see also page 501).

The roller drive is by a small electric motor working through a reduction gearing. The roller unit itself is usually removable and connected to the motor by a simple dog and pin coupling.

The roller layout involves, as indicated, a minimum of two activator and two final squeegee rollers. Most machines have however one or two extra activator rollers to apply more solution to the print surface and to increase the paper path (and hence the processing time) through the activator stage. There may also be an extra roller to apply stabiliser to the print surface before the paper is submerged in the stabiliser solution itself. An alternative is to have a number of stabiliser rollers, all applying the solution to the print surface only. As the print is there not submerged in any solution, it comes out of the machine in a drier state.

Various refinements on some machines permit easy draining and/or semi-automatic replenishing of the solutions in the trays.

Roller processors are also becoming more popular for black-and-white papers intended for conventional development, though here the processing time is necessarily longer. Even so, it is appreciably speeded up by working at a high solution temperature (around 40°C) which cuts the total processing time to about 45 seconds. Such processing units combine the advantages of roller processing (fast access and easy handling) with the superior stability of papers using a conventional developing/fixing procedure.



Normally the relay 1 is energised by current flowing through the trigger tube 3 which is kept conducting via the capacitor 5. In this state the contacts of the relay 1 are kept open and the enlarger lamp is switched off. To switch on, the switch 4 is closed, discharging the capacitor 5 and rendering the trigger tube 3 non-conducting so that the relay contacts are allowed to close and the enlarger lamp comes on. On releasing the switch 4 immediately, the capacitor 5 charges through the variable resistor 2, and when it reaches a sufficient charge renders the trigger tube 3 conducting again. The relay contacts then open to switch off the enlarger lamp. The charging time of the capacitor, and hence the exposure time, is controlled by the resistor 2 which can be calibrated in seconds and fractions of a second. Alternative capacitors can be switched in to provide several setting ranges.

Modern electronic timers use transistors and other semiconductor elements in place of the trigger valve and relay but operate on the same principle.

After emerging from the roller processor the print may be dried by warm air in about half a minute or – in the case of stabilisation papers – by passing over a heated roller so that the print emerges bone dry within 10 to 15 seconds.

DARKROOM TIMERS

The correct measurement of time intervals plays quite an important part in the darkroom. Correct exposure time is obviously vital in enlarging, but correct time of development is equally important for reproducible results. No good darkroom can be without accurate clocks.

These can be divided into three groups. The first comprises in principle normal clocks for timing longer intervals from a minute or so up to 1 or 2 hours. They serve for controlling processing, and the most practical types have a large face with clearly marked figures. The clock may have two hands, one for intervals up to 10 minutes and graduated in ¼ minute divisions, and the second one for times up to 60 or 120 minutes. The hands can be reset to zero at the start of the operation to be timed.

Seconds timers working on the same principle have a seconds hand as well as a minute hand and can serve for timing both exposures and processing steps.

The second group is that of alarm timers. These are set by turning a hand to the interval required on the dial. This at the same time winds the mechanism. On starting the clock, the hand runs back until it reaches zero, when a signal bell rings. The setting ranges of various models extend from 10 minutes up to 2 hours, sometimes in two ranges. Such a two-range version, with one hand covering 10 minutes in ¼ minute divisions and the second one indicating the longer intervals, is the most versatile type.

A variation of this is the programmable timer where a number of time intervals may be set on a large dial – usually with adjustable riders. At the end of the first period set the timer stops and rings a bell signal. You restart it after having carried out the appropriate processing step (e.g. changing solutions in a tank) by pressing a button. The timer then runs on to the end of the second preset period to stop and ring the bell again. The number of intervals that can be programmed into such a timer depends on its overall

running range and the number of tripping riders attached to the dial or scale.

The third kind of timer incorporates a switch circuit for switching the enlarger on and off for a pre-set exposure interval. Here again there are several systems. The simplest and most robust are clockwork models similar to the alarm timers mentioned above. Starting the timer switches on the enlarger lamp, and when the hands have returned to zero the lamp switch opens. Usually there is also provision for switching on the lamp without setting the timer going, to permit focusing and arrangement of the image on the baseboard.

With some clockwork time switches the hand remains at the selected time indication while the mechanism runs down. This saves time when making a number of prints with the same exposure, since the timer does not have to be reset constantly.

Electronic timers rely on the gradual charge or discharge of a capacitor circuit to operate the switch which disconnects the enlarger lamp. Different time intervals are obtained by adjusting a variable resistor in the circuit. The electronic timer involves no moving parts, but the accuracy of cheaper models may vary with for instance different ambient temperatures which affect circuit characteristics. On the other hand electronic timers can handle a particularly wide range of intervals, down to a fraction of a second. The most sophisticated versions indicate the set time in a digital readout with light-emitting diodes similar to an electronic calculator. During the exposure (or other timed switching function) the digital readout runs backwards, so showing the still unelapsed time at any instant. That facilititates for instance shading and similar control operations.

Many models of such enlarger time switches are available, and the choice depends to some extent on the nature of the light source to be controlled. The instrument must be suitable for the current it has to handle, otherwise the switch contacts are likely to be damaged.

THE CARE OF DARKROOM EQUIPMENT

The proper care of apparatus and appliances calls for particular attention, if only because of the humidity of the atmosphere and proximity of chemicals.

Firstly, every effort should be made to keep all woodwork reasonably waterproof. This applies not only to items in constant contact with water (page 230) but also the woodwork of cupboards, light-tight boxes and other furniture. These should all be kept clean and periodically polished. In professional darkrooms this should be a fixed routine.

Iron or steel baths that have become rusty should be thoroughly cleaned and freed from rust by brushing with a steel brush, then given a priming coat of red or white lead and finally a coat of enamel or of good varnish. All moving metal parts, or those which are inconvenient to paint or varnish, should be rubbed clean and then given a very thin coat of acid-free paraffin. Thin sewing machine or typewriter lubricating oil can also be used. Do not forget to lubricate hinges and similar parts.

Print washing machines should be emptied when not in use, and drained and kept dry until wanted again. If allowed to stand full of water for any length of time, a slimy growth of algae may take place. This is difficult to remove and can attack the lining or finish of the apparatus.

Glazing machines (page 363) call for particularly careful handling and should always be cleaned up and covered after use.

It goes without saying that all surfaces in contact with developing dishes, tanks or processors need frequent wiping. Any splashes or spilled solutions should be wiped up immediately before they have a chance to dry up and release chemical dust into the atmosphere of the darkroom.

All working surfaces need periodic dusting; dust collects especially on the floor.

The enlarger itself should be kept under a dust cover when not in use (page 172), while accessories such as masking frames, spare negative carriers etc. are best stored in closed drawers or cupboards.

Enlarging Practice

So far we have dealt with the theoretical points concerned with enlarging, the desirable qualities of negatives and printing papers, the general principles of choosing a suitable type of paper for a given negative and the design and choice of equipment. Now we come to the actual practice.

EXAMINING NEGATIVES FOR ENLARGING

To match the negative with a suitable paper grade, the negative image itself must be carefully examined. Differences in negative range or gradation are due to (1) the emulsion itself; (2) the developer; (3) variations in exposure; and (4) variations in developing time. Generally the shadows show whether a negative was correctly exposed.

(a) *Lack of shadow detail* with not very dense highlights indicates underexposure; such a negative will have a short range requiring a hard paper grade. Even this cannot however bring back shadow detail which was missing in the first place.

(b) *Full detail in both shadows and highlights* indicates correct exposure. With correct development this yields a negative of normal range, suitable for printing on a normal paper grade.

(c) *Veiled shadows and clogged up highlights* with little gradation are due to overexposure. Despite the high maximum density, this leads to negatives of shorter range requiring again a harder paper grade. Highlight detail will however be poorly differentiated.

With correct exposure the appearance of the highlights indicates roughly the degree of development.

(d) *Low highlight density* with slight detail and low contrast is due to too short development. The negative range is again short, and requires a hard

paper grade. Unless development was excessively short, prints with full tone detail are still possible.

(e) *A correctly developed* negative shows full shadow detail and contrast as well as reasonably strong highlight detail. This should be printable on a normal paper grade.

(f) *Very dense and clogged up highlights* with normal shadow tones and high contrast are generally due to excessive development leading to a very long negative range. Such a negative is likely to be grainier than a normal one, but can successfully be printed on a soft paper grade.

Consistency in enlarging therefore is closely linked with correct negative exposure and especially development. By consistent camera and processing technique many professional photographers manage not only to match the majority of their negatives to the same paper grade, but even to the same printing exposure under otherwise equal enlarging conditions. This of course saves a great deal of time in grading negatives for printing, as well as over exposure tests. It is the first essential step to rationalisation in professional enlarging practice (page 253).

THE CHOICE OF PAPER GRADE

As already noted on page 88 the exposure scale of the paper grade must be matched to the density range of the negative. Usually this is done visually, and after some practice it is not too difficult to judge negatives fairly reliably.

In the beginning, negative characteristics likely to be misleading are inadequate or excessive density due to under- or over-exposure. Grossly underexposed negatives may often have to be discarded; with heavy overexposure and the consequent high overall density (plus sometimes fog) it becomes a little difficult to judge whether the negative underneath all that murk has a short or a long density range.

The alternative is to measure the most significant highlight and shadow tones of the negative. This can be carried out with a densitometer. However, measurement of the image projected on the baseboard is more reliable for two reasons: (1) the measurement automatically allows for any Callier factor and flare in the optical system of the enlarger,

and (2) the readings can be used for immediate exposure determination at the particular magnification employed. We shall come back to exposure measurement on page 263.

An incorrect match of negative and paper grade will be immediately apparent from the print image. Thus:

(a) If the print has – (i) black shadows but the highlights are only dull grey; or
(ii) the highlights are correctly white, but the shadows only grey without a full black tone;
– *the paper was too soft.*

(b) If both highlights and shadows record correctly as full white and dense black respectively, but including full detail at each end of the scale,
– *the paper was of correct contrast.*

(c) If (i) the highlights are correct, but shadows are dense black without detail; or
(ii) the shadows are correct but highlights are chalky and burnt out; or
(iii) detail is lost at both the shadow and highlight ends of the tone scale;
– *the paper was too contrasty.*

CORRECT EXPOSURE IN ENLARGING

As with negatives, some experience is required before enlarging exposures can be correctly judged. The principal difficulty in dealing with printing papers is that they have very little exposure latitude. For this reason it is desirable at first – or on any occasion where the correct exposure is in doubt – to make a simple test before actually exposing a full print.

To save paper it is best to cut a strip only from the make and grade to be used. This should be about as long as the short side of the print format, and about a couple of inches wide. This is placed on the easel or baseboard in such a way that it covers portions of the image containing both the lightest highlights and the deepest shadows present in the picture.

When judging exposure times by this method the exposure must always be adjusted so that the print develops fully within a given time. This time depends only on the developer and its temperature. In enlarging it is not practical to compensate exposure errors by prolonged or shortened development. The former is liable to lead to fogging, and the latter to poor print tones.

Exposing the test strip is quite a simple matter. Have a piece of black paper or card ready, large enough to cover the whole strip. Start with the strip fully uncovered, and switch on the enlarger lamp. After 2 seconds cover up a small section of the strip with the card. Cover up further sections after 3, 4, 6, 8, 12, and 16 seconds, leaving only the last section exposed. Switch off the enlarger after 24 seconds. A guide for moving along the card in equal steps helps in identifying which step is which later on.

After development it is then easy to check which of these exposures looks most nearly correct. If all the steps are too light, increase the lens opening by at least 2 to 2½ stops; if this is not possible, increase all exposures by a factor of 6. (If the enlarger requires exposure times that long with a normal negative and a medium magnification, the lamp is too weak. In that case fit a light source of higher intensity to obtain more convenient exposure times.)

If all strips are too dark, stop down the lens by 3 stops and repeat the series.

When examining the developed strip, observe the highlights, as they are the best indication of the exposure:

(a) Where the highlights are white and chalky, and the shadows only medium grey without any full black, *the exposure was too short.*

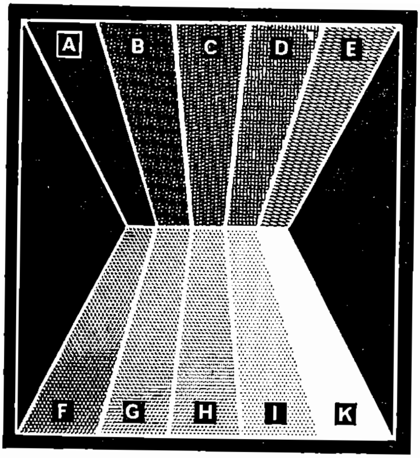
(b) Where the highlights contain almost clear white and show full detail, but the densest shadows of the image contain a full black and still show details, *the exposure was correct.*

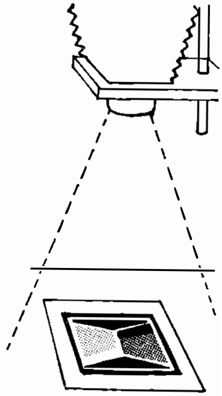
(c) If the highlights appear veiled over and grey, and the shadow details are too dark to be seen, *the exposure was too long.*

For this assessment it is of course essential to have a reasonably representative image portion on the step judged as correct. For that reason many people prefer, after some experience, to make a test print of about one-fifth of the total picture area, giving an exposure estimated in the light of previous experience. From this first approximation it is often easier to decide the correct final exposure.

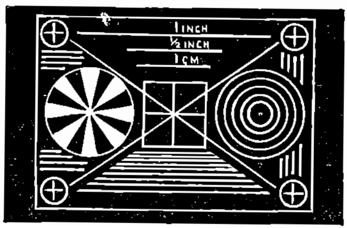
STEP WEDGE TESTS

There are a number of devices which simplify the exposure of test strips. The simplest consists of a frame holding the

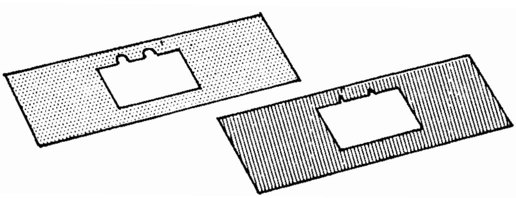


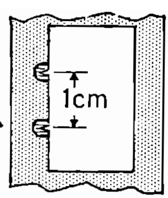


Above: A step wedge – preferably of a radial layout of the steps (going out from a comparatively small central area) – placed over a piece of printing paper during a test exposure provides a quick alternative to test strips for exposure estimation.



Above: A focusing negative placed in the negative carrier while setting up aids precise focusing, as it is easier to judge the sharpness of fine lines. If the focusing negative also incorporates lines of marked length, measurement of their image on the baseboard gives a quick indication of the magnification. See also page 251.





Another way of checking magnification is to cut fine marks 1 em. apart into the edge of the mask in the negative carrier. With double plate glassless carriers it may be necessary to cut the marks in the frame of one plate, and make larger cut outs in corresponding positions in the other – so that the marks are easily visible on projection (*right*).

paper and a movable sliding cover which is advanced by hand from one exposure to the next.

More convenient is a grey scale having different densities instead of using different exposure times. This is a circular or rectangular area of separate steps, which is laid on a small piece of the paper to be used on the baseboard of the enlarger while the negative is in the carrier. The paper underneath the grey scale receives an exposure of say 1 minute. After development of the test print the result obtained is similar to that by making a series of step exposures. The steps are numbered or lettered to give the actual exposure time required for a correct print either directly or with the aid of a simple calculator.

A practical wedge for this purpose might consist of eight steps of ascending densities as indicated in Table XI below.

XI – EXPOSURES FROM GREY SCALE TESTS

Step	*Density*	*Print Exposure**	*Step*	*Density*	*Print Exposure**
A	1·48	2	F	0·70	12
B	1·30	3	G	0·58	16
C	1·18	4	H	0·40	24
D	1·00	6	I	0·28	32
E	0·88	8	K	0·10	48

* In seconds, for an overall test exposure of 1 minute.

The column headed "Print exposure" gives the exposure time for a correct print corresponding to the wedge step which gave an image of correct depth with a total exposure time of one minute. This is a fairly accurate guide to the final print exposure made with the same negative on the same paper.

For example, if step D turns out to be the best exposed portion, the correct print exposure would be 6 seconds.

For very dense or very thin negatives the basic exposure under the wedge can of course be increased or decreased. In that case, i.e. when all the steps printed through the wedge are either too dark or too light, a change by factor of at least 6× down or up will be necessary to bring a correctly exposed step somewhere near the middle of the range.

Such a step wedge can also be used to obtain a direct indication of the paper contrast grade. For this the paper is simply exposed under the wedge (without a negative), choosing an exposure – after tests – to get both a pure white and a full black on the paper. The number of test fields between (but not including) black and white are counted. If there are eight such intermediate steps visible, the paper is a normal grade. With six to seven steps the paper is hard, while with less it is extra hard. If the paper is softer than normal, it will be impossible to get both a full black and a pure white; all ten steps will be light to dark grey.

MAKING THE EXPOSURE

The exposure of the actual print is best made by switching the enlarger lamp on and off. If the enlarger is at all shaky – i.e. not anchored to a wall (page 166) and the darkroom located on an upstairs floor of a normal house, it is best to stand still and wait for about 10 seconds before making the exposure. This permits any vibration of the enlarger to die down. For the same reason do not make the exposure immediately after touching the enlarger. The ideal way is with a timer which switches on the enlarger lamp and automatically switches off again at the end of the pre-set exposure time (page 236).

Many enlargers are fitted with an orange or red filter which can swing in front of the lens to permit accurate location of the enlarging paper on the baseboard without fogging. Some workers expose by swinging the filter aside; the risk of producing a blurred print through shaking the enlarger slightly is appreciable with this procedure.

The paper may be held down on the baseboard by drawing pins or darkroom pins. The latter have larger shaped heads for easier gripping.

While pins may be necessary to hold down flat large paper formats, smaller papers are best held in a masking frame, This carries adjustable masking strips or bands which not only hold the paper down flat but at the same time produce neat white borders around the print. Masking frames are available in various sizes and types. The most popular formats are 20 × 25 and 25 × 30 cm or 8 × 10 and 10 × 12 inches. Really large masking frames (up to 40 × 50 cm or 16 × 20 inches) are less convenient if most prints are made

in smaller sizes – this is where darkroom pins are handy for occasional big prints. See also page 257.

EXPOSURE AND MAGNIFICATION

Where several enlargements of a different size are required from one negative, the correct exposure for the print naturally depends on the magnification used. If a correction factor is known for different magnifications, only one exposure test will be necessary.

The necessary correction factor depends on the lighting system of the enlarger. With fully diffused enlarger illumination the exposure is proportional to the square of the magnification. Thus if we go from a $3\times$ enlargement to a print with a magnification of 5 diameters, the exposure increase would be $(5/3)^2 = 2\frac{3}{4}\times$.

With condenser enlargers the exposure relationship at different magnifications is more complicated. It depends on a number of factors, such as the size of the light source, the position of the lamp relative to the condenser, the position of the negative in front of the condenser and so on, For an enlarger with semi-diffused illumination (opal lamp and condenser – page 130) a doubling of the magnification requires an exposure increase by a factor of about $3\times$. Table XII (page 247) shows approximate exposure relationships.

More precise correction factors for a given enlarger and enlarging lens can be obtained by making a series of test exposures (for example through a grey scale as described on page 244) and establishing the correct exposure at each magnification. These exposures can then be plotted on a graph against the magnification to permit interpolation of intermediate values. To find the exposure correction for a change of magnification it is then only necessary to look up *on the graph* the correct exposure a at the magnification at which you have established the right exposure for a specific print, and the exposure b on the graph for the magnification at which another print is to be made. Then multiply the exposure determined for that negative by the factor b/a.

The values of a and b on the graph will of course be different from the exposure obtained for a given negative being printed. This does not matter, since it is ratio of b to a which counts.

XII – MAGNIFICATION AND EXPOSURE

Magnification	*Relative Exposure with* Semi-diffused Enlarger*	*Relative Exposure with* Fully Diffused Enlarger
2×	1	1
2½×	1·4	1·5
3×	1·8	2·3
3½×	2·4	3
4×	3	4
4½×	3·5	5
5×	4·2	6·3
6×	5·6	9
8×	9	16
10×	14	25
12×	19	36
14×	25	60
16×	30	65

* i.e. Opal lamp with condenser. The figures are average only and liable to vary somewhat with different enlargers.

WORKING WITH VARIABLE CONTRAST PAPERS

Variable contrast papers use a mixture of soft working and contrasty emulsions. Different contrast grades are obtained by controlling the colour of the exposing light with a range of yellow (and sometimes also blue) filters of different depth (page 105). Table XIII shows the effect of a typical filter system with a variable contrast paper. The filter range differs with different makes; the effect of the filters may also be reversed, for instance blue-filtered light giving the greatest contrast and yellow-filtered light the least. Any variable contrast paper should always be used with the filter set produced by its manufacturer.

XIII – VARIABLE CONTRAST FILTERS

Filter	*Colour*	*Contrast obtained*
No. 1	Pale blue	Very soft
No. 2 (or none)	Very pale blue	Soft
No. 3	Pale yellow	Normal
No. 4	Light yellow	Vigorous
No. 5	Medium yellow	Hard

The range of filters to be used for a variable contrast system also depends on the enlarger light source. Thus a paper using increasingly yellow-filtered light for higher contrast would require deeper yellow filters for a given contrast with cold cathode lighting (which is richer in blue) and paler yellow filters with tungsten lighting.

The light source must however still be reasonably white or at least with comparable emission in both the yellow to red and the blue spectral bands. Mercury vapour lamps – with practically no red emissions – are thus not usually suitable for printing with variable contrast papers.

The filters for contrast control are made of varnished gelatine or acetate film, mounted in cardboard holders. The filters are held below the enlarger lens, and are thin enough not to upset the image definition or to cause register trouble when using split exposure techniques (page 252). Special supports are available for holding the filters below the lens of a vertical enlarger; this leaves both hands free for other manipulation. Alternatively the filters may be fitted in a filter turret (page 201).

To try out the paper for the first time, select a negative of medium contrast and place it in the carrier of the enlarger. Determine an exposure which gives approximately the correct density in the middle tones of the print by the usual test strip method, with a medium contrast filter held in the light beam. Then make exposures on five sheets of paper using the filters and exposure factors indicated by the manufacturer. This experiment will demonstrate the various results which can be obtained with a variable contrast paper, and the effect of the filters on the print contrast.

Still finer control is possible by exposing partly through the high-contrast and partly through the low-contrast filter. First make test strip prints with the low contrast filter to find the time needed to print the middle tones of the negative to correct depth. Then use a scheme like that of Table XIV on page 249 to allot the times of the low contrast and high contrast portions of the subsequent mixed light exposure. The unit of time in the table is one-tenth of the time required to make the test print mentioned.

One difficulty of mixed light techniques is that the two filters have different exposure factors. For a given minimum density in the print, the exposure through the low-contrast

XIV – MIXED LIGHT TECHNIQUE (TWO FILTERS)

Relative Exposure Times		
Low Contrast Filter	*High Contrast Filter*	*Apparent Print Contrast*
10	0	Very soft
$7\frac{1}{2}$	5	Soft
5	10	Normal
$2\frac{1}{2}$	15	Hard
0	20	Extra hard

filter may thus be much less than through the high-contrast filter. In the Table XIV above, the factor ratio for the two filters is assumed to be 1 :2 – which is not necessarily always the case. But this ratio illustrates also how intermediate contrasts can be split. For the calculation, decide on the number of exposure units desired through the low contrast filter, subtract this from 10 and multiply the remainder by 2 to get the exposure through the high contrast filter. For example, with 4 exposure units through the low contrast filter the remainder is 6 units; $6 \times 2 = 12$, which is the relative exposure through the high-contrast filter. For other filter ratios set up a scheme like Table XIV by multiplying the remainder in each case by the ratio of the filter factors of the low-contrast to high-contrast filter.

A useful way of simplifying the calculations is to "load" the low-contrast filter to bring its exposure factor to the same level as of the high-contrast filter. With a 2:1 ratio this involves combining the low-contrast filter with a neutral filter of 0.3 density.

Make a test strip as before to find the correct exposure for the middle tones, and then simply split this time into high and low contrast exposures according to the required gradation – without any exposure factors. Thus if a test required 24 seconds for the middle tones, give 12 seconds each through the low and high contrast filters for normal print gradation. For higher contrast the ratios might become 6 and 18 seconds or even 24 seconds through the high contrast filter alone. Conversely we can for lower contrast allot a greater proportion of the 24 seconds to the exposure through the low contrast filter (with neutral density filter). The only drawback of this loading technique is

that overall exposures – except for the most contrasty prints – are longer.

The mixed-light technique can also be used with one filter only – the high-contrast one. The test strip for the middle tone exposure is in this case made without a filter, and the no-filter and high-contrast filter exposures split in a similar way to that shown in Table XIV (the high contrast exposures are however in this case somewhat higher).

The softest contrast obtainable in this way is slightly less than with two filters, but the single filter method lends itself to the use of a ring filter in the enlarger lens. For this a circle of the high contrast filter is cut to fit between the lens components (provided that the lens is easily separated) close to the iris diaphragm. The centre of the filter disc carries a hole of the same diameter as the smallest aperture of the lens. With the lens fully stopped down, the light used in enlarging is thus unfiltered. As the aperture is opened, more and more of the light reaching the paper will be modified by the filter. Some preliminary experiments with the enlarger so fitted will provide the necessary information to make a working chart showing the contrast resulting from each aperture setting.

Multi-filter techniques also permit local control of contrast where negatives are difficult to print.

For example a landscape negative may contain an area of cloud and sky which is dense and hard, while the foreground detail is both thin and low in contrast. When a negative is printed with sufficient exposure to record the clouds on the print, the foreground often becomes too dark to show detail. One way of printing such negatives is to shade the foreground (page 412). But with a variable contrast paper it is possible to obtain better results by combining this with a slight variant of the mixed light technique just described, thus allowing for the difference in contrast between the highlight and shadow regions. For this purpose the paper is exposed through the high contrast filter until the shadows are of correct depth. This exposure is then followed by an exposure through the low contrast filter to give the highlight detail (established by a preliminary test) while the shadows are held back by local shading. If the contrast of the highlight areas is less extreme, one of the intermediate filters can be employed for the second exposure.

When controlling contrast in this way, the high-contrast exposure should however always be made first.

FOCUSING

Enlargers without automatic focusing (page 152) must be focused by hand. If the negative has no suitable fine (and contrasty) detail for this purpose, small scratches on the emulsion may be used as a guide to sharp focusing.

If the negative happens to be dense, visual focusing is sometimes difficult and a separate focusing negative is useful. Such focusing negatives are available ready made, and consist of a number of very fine and transparent lines against a dense background. A piece of fogged film can also be turned into a focusing negative by developing it to an even dense black and scratching fine lines on it with a needle. Alternatively, fine lines can be drawn on a clear film with indian ink.

The focusing negative must always be in exactly the same plane as the negative to be enlarged will later occupy. Otherwise the latter will obviously not be in sharp focus.

If the focusing negative also contains a line of accurately measured length (for example 1 cm) this provides a ready indication of the exact magnification on the baseboard. We only have to measure the length of this line in the projected image with a ruler – for instance if it appears 6·5 cm long, the magnification is 6·5 diameters.

Alternatively, two marks can be made spaced exactly 1 cm apart in the negative carrier. If a plastic negative mask is employed with a glass sandwich carrier, two pinpricks near the edge of the mask will serve the purpose. With glassless carriers very fine notches may be cut 1 cm or $\frac{1}{2}$ inch apart in the edge of the film aperture of the lower carrier plate. A slightly larger notch may be necessary in the same position in the upper plate, so that the marks are plainly visible in the edge of the projected frame opening of the carrier (page 243).

THE SEQUENCE OF OPERATIONS

Having dealt with the more important details of manipulation individually, we can now list a step by step sequence of making an enlargement with some general hints.

(1) An important preliminary point is scrupulous clean-

liness. Every single grain of dust is important, for every grain is capable of producing a more or less intrusive spot on the enlargement. So make it a rule to guard against dust at every point. The first step is of course to keep the darkroom itself spotlessly clean. Further, every negative should be carefully dusted with a fine camel hair brush kept solely for this purpose.

So-called anti-static brushes – which contain a strip of weakly radio-active substance – immediately discharge any electrostatic charge generated by dusting or rubbing. Such electrostatic charges on the film surface would otherwise attract more dust.

Guard also against fingerprints, wet, greasy or otherwise. So handle film only by the edges, and never touch the film surface with the fingers. If the negative should have got scratched, it can be treated as described on page 455.

(2) If a negative carrier with glass plate is used, this must be kept equally clean and free from fingermarks or dust. The same applies to the condenser and the lens of the enlarger. When not in use the enlarger should therefore be covered (page 177). Dirt in optical components scatters light and reduces the brilliance of the enlargement.

(3) Next introduce the negative into the carrier and switch on the enlarger.

As stressed before (page 121) the light should be evenly distributed over the whole area of the negative. Also there should be no reflection of light from any part of the enlarger or from any neighbouring area (page 207). Light scatter by reflection can also be reduced by masking down the negative in the carrier to the actual area being printed. This can improve picture quality where only a small part of the negative is being enlarged. Above all make sure that no light is projected on to the baseboard through the clear edges of the film.

(4) Next adjust the enlarger lamphouse so that the negative portion to be enlarged fills the area of the paper format to be used. (Check on a sheet of plain paper of the same size, or on the masking frame.) Focus for maximum sharpness.

Since focusing slightly alters the scale of the image, some readjustment of the enlarger head may be necessary. This does not apply to automatic enlargers which keep the image in sharp focus as the enlarger head is raised or lowered.

(5) Adjust the masking frame (if used) to the exact print size and the width of the borders required.

(6) Now determine the required exposure time by tests or with an enlarging exposure meter (page 263).

(7) Switch off the enlarger lamp or cover the lens with its orange filter while placing the sensitive paper in position.

(8) Obviously the paper must be protected from white light at all time. So never leave paper lying unwrapped in the darkroom. Either repack it at once – after unpacking a sheet required for a print – or keep the paper in a light-tight drawer or box.

(9) While making the actual exposure avoid all vibration or shaking of the enlarger (page 245).

(10) Then process the print (page 323).

PROFESSIONAL RATIONALISATION

For the amateur, making enlargements is usually a fairly leisurely business. So the fact that trial and error methods and tests take a lot of time is not important.

The commercial darkroom operator's concern is not only to turn out high-quality prints but to do so economically in materials and time. Professional darkroom technique – while in principle very similar to the amateur's methods – involves extensive rationalisation and standardisation to maintain a high output of good prints with the lowest possible wastage.

(1) Standardisation starts long before the enlargement process with controlled negative quality – both in terms of density – by controlled negative exposures – and of contrast, by standardised processing (page 69).

(2) Professional enlarging equipment is designed for greater handling convenience and hence speed (page 186). Thus enlargers usually feature automatic focusing and other refinements.

(3) In the photographic departments of commercial and other organisations the majority of prints required are of one or two specified sizes and contrast grades. This implies working to the same degree of enlargement a lot of the time, which again speeds up work.

(4) Frequently bulk orders of prints are called for, for instance to illustrate press releases concerning a manufacturer's product. Once the enlarger is set up, identical

prints can be exposed in rapid succession and are processed by another operator. Alternatively, the enlargements may be exposed on a continuous strip of paper in a roll paper cassette (page 259) and the whole roll developed in one operation. (Sometimes large bulk printing orders are met by making one or more enlarged copy negatives and printing those on contact printers.)

(5) Enlarging exposures are rarely determined by test strips; most operators employ some form of exposure measurement (page 263). Generally the more automatic integrating methods are chosen for speed. The operator's skill then consists of estimating and applying the necessary overriding correction to deal with negatives of abnormal brightness distribution and occasionally also of non-standard density or contrast.

(6) Processing is equally rationalised, with standard solutions often on tap at the processing work station. Prints are passed through the solutions on a continuous flow principle, so that each print receives the same time in the developer and approximately the same time in the fixer.

Where paper is used in roll form, processing is carried out by a continuous running machine which leads the 30 metre (or longer) paper strip through tanks containing the various solutions. As the paper is pulled through at a steady rate, the time it spends in each solution is controlled by the length of the paper path through that processing tank. Generally continuous processors are however more used in photo finishing laboratories than in the darkroom of a professional photographer.

(7) Finally, commercial darkrooms employ trained processing and printing operators. The professional or industrial photographer rarely does his own processing or printing – his time is usually fully taken up with running the studio or department and supervising camera operation. Only the one-man studio or freelance photographer still processes and prints his own pictures; for him rational and time-saving working is particularly important.

Aids to Enlarging

Certain practical accessories for enlargers can greatly simplify specific handling aspects. We are concerned especially with (1) paper holders, (2) focusing aids and (3) instruments to determine the correct enlarging exposure. We shall here deal with the first two items; methods and equipment for more sophisticated exposure measurement are discussed in detail in the next chapter (page 263).

MASKING FRAMES

The purpose of the masking frame is to hold the enlarging paper in position on the baseboard and usually also to mask off the paper edges to provide white print borders. In its simplest form the frame consists of a wooden or metal base and a hinged on L-shaped frame which can be raised or lowered. The two arms of the L hold the paper edge along two sides. The frame further carries masking strips of thin black metal which can slide along the arms of the L and hold down the other two edges of the paper. By sliding the strips – which are graduated in inches and/or centimetres to show the size of the image area – the frame can be set to take and hold flat papers of different formats. Sometimes the outer ends of the L are connected by a supplementary frame for greater rigidity.

The largest paper size accepted naturally depends on the dimensions of the frame. Masking frames exist up to 40 × 50 cm or 16 × 20 inches large, but become difficult to handle and bend easily. Also if small prints are required, the paper is awkward to insert into a big frame – even when the masking strips are slid into the correct format. For this reason a 20 × 25 cm or 8 × 10 inch frame is useful when most of the printing output is of prints smaller than this; a second frame could still be used for really big enlargements.

Underneath the hinged L arm paper stops are usually set into the base of the frame. These serve for locating the paper when inserting it into the frame. The procedure of

loading the masking frame – once the sliding strips have been adjusted to the right image size – is thus very simple: open the hinged top, place the paper in position against the stops on the base, and bring down the top again.

The paper stops may be adjustable, giving wider or narrower white margins along the top and left-hand edge of the print. The margin at the right-hand and bottom edges is determined by the position of the masking strips. For example if a 5 mm wide border is wanted all round on 20 × 25 cm or 8 × 10 inch print, the paper stops are set to 5 mm and the masking strips to an image area of 19 × 24 cm. This automatically leaves another 5 mm of border underneath the masking strips. The adjustment range for the border usually varies from about 3–25 mm or $\frac{1}{8}$ to 1 inch.

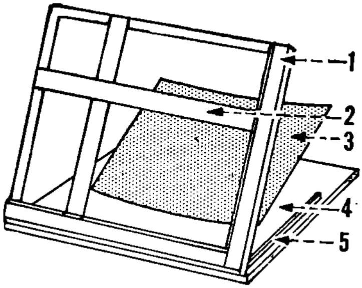
An alternative design is a magnetic paper holder with a steel base and no hinged top frame at all. The masking strips are instead laid on top of the holder to slide along rails and are held in position by small magnets incorporated in the strips themselves. This simplifies insertion of the paper, and in particular makes the frame less liable to slide about on the baseboard during handling.

BASE CORRECTION AND LOCATION

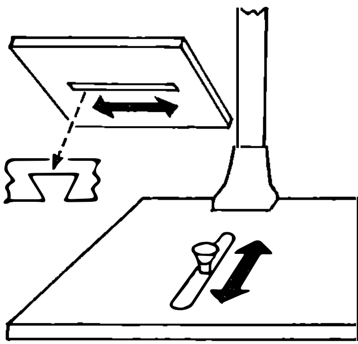
When a masking frame is used with an automatic focusing enlarger, the print surface is of course raised above the enlarger baseboard by the thickness of the masking frame base. The focusing adjustment of the enlarger therefore requires compensation – either by raising the whole enlarger head (where the automatic focusing movement is built into a parallelogram system) or raising the column in its base. This adjustment must exactly match the thickness of the masking frame base, but need not be disturbed again if the same frame is used all the time.

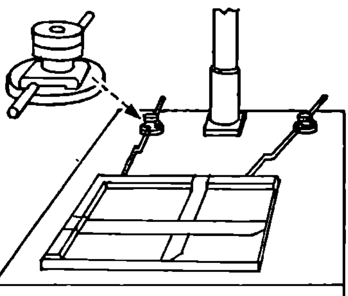
There are also masking frames which have no base; a heavy supporting frame rests directly on the enlarger baseboard, and carries the hinged L-frame with its masking strips.

A big advantage of using a masking frame is that it facilitates accurate composition of the projected image within the picture area to be used for the enlargement. And once the masking frame is located in the right position, it is easy to insert the paper without the need for an orange

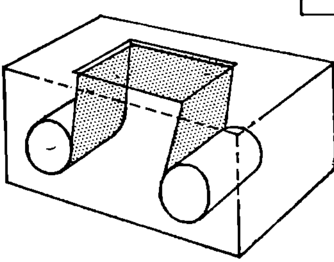


Adjustable masking frame. 1, main frame; 2, sliding masking strip; 3, paper; 4, base; 5, edge stop (often adjustable).





A locating system for the masking frame is useful, as it keeps the frame firmly in position on the baseboard once the required picture area is determined. One method (*upper right*) has a sliding pin in a vertical slot in the baseboard, and a horizontal groove in the underside of the frame. This permits free movement in any direction, and the frame can be clamped in position by a lever which pulls down the sliding pin and so presses the masking frame against the easel. Alternatively, hinged rods attached to one side of the frame may be clamped in position by a locking device on the easel (*lower right*).



A roll paper cassette takes continuous rolls of paper up to 75 m long. The paper runs past the exposing aperture in the top plate and is advanced after every exposure. See also page 259.

E.—Q

filter over the enlarger lens to position the paper afresh. For this the masking frame must however sit firmly on the enlarger baseboard. Usually the weight of the unit and sometimes small rubber feet underneath help to keep it in position. There are also systems for clamping the frame positively in the selected place on the easel.

One method employs a masking frame with a horizontal keyed groove in the base. The enlarger baseboard has a vertical slot along part of its width, with a headed pin which is movable forward and back along this slot. This pin is held captive in the groove of the masking frame. In this way, with the pin sliding both in its slot and in the groove of the masking frame, the latter can be positioned anywhere on the baseboard but not lifted off. A locking lever can pull the pin downwards, clamping it against the groove of the masking frame and so locking the latter in place wherever wanted.

A second system is applicable to any enlarger and uses a pair of cranked rods attached by ball joints to two points on the masking frame. The rods slide freely in separate clamping fittings attached to the edge of the baseboard. On screwing down the fittings, the rods – and with them the masking frame – are securely clamped in any position. (See also page 257.)

BORDERLESS AND BLACK-BORDER ENLARGEMENTS

The simplest way of making enlargements without a white border is of course to trim this border off the finished print. There are also masking frames which eliminate the need for trimming; here the paper is held in position by a hinged glass plate instead of by masking strips. This has only one drawback: the glass must be kept scrupulously clean. Another way of holding the paper in position without glass and without masking strips is on a vacuum easel (page 196). Small vacuum easels are also available for placing on the enlarger baseboard in the same way as a normal masking frame.

Borderless frames may hold the paper in position by the edges of the masking strips themselves which slide in contact with the frame surface. Usually a slight springiness of the strips (or of corner pieces) and a slightly inclined flank of the strips holds the paper by the edge of the latter. Such retaining strips or corners can be used with magnetic paper holders

(page 256). This way of holding the paper for borderless enlargements is effective with double weight material; with very thin papers it does not always hold the paper completely flat.

For black borders a mask is necessary which covers the image area on the paper, while the surrounding border receives a fogging exposure. Accordingly a separate mask is needed for every picture size. This can even be home-made from flat sheet metal or plywood, painted black. The edges must however be absolutely straight, since any raggedness will show up on the print. The edge should also be bevelled, to avoid casting a blurred shadow and to ensure that the border is really sharp.

To make the black border expose the paper in the usual way. Then switch off the enlarger, place the mask on the paper so as to leave free the area required for the border. Remove the negative carrier from the enlarger and give the print – which must not have been moved on the baseboard – another exposure of the same length as was used for making the enlargement.

ROLL PAPER CASSETTES

These hold paper in continuous rolls for high volume commercial enlarging. The cassette consists of a light-tight box containing a feed and take-up spool for the paper, an exposing surface on top of the box and light-trapped slots through which the paper is threaded from the inside of the box on to the exposing surface (emulsion upwards) and back on to the take-up spool in the box again.

Roll paper cassettes can take rolls in widths up to 28 cm or 11 inches and lengths up to 75 m or 250 feet. Guides adjust the cassette to different roll widths. The exposing for any given image size within the width of the paper used. The take-up spool is motor driven, and can advance the paper by an adjustable interval according to the print format required. In this way a large number of enlargements can be exposed on the paper roll, which is then processed as a whole in a continuous processing machine. Since this system reduces paper changing between prints to pressing a button to advance the paper in the cassette, prints are made as fast as they can be exposed.

Usually a light-tight cover closes the exposing surface when not in use, so that the cassette can be left loaded for longer periods even when exposures are made only intermittently. Equally, shorter lengths of exposed paper can be cut off and removed for processing.

AIDS TO FOCUSING

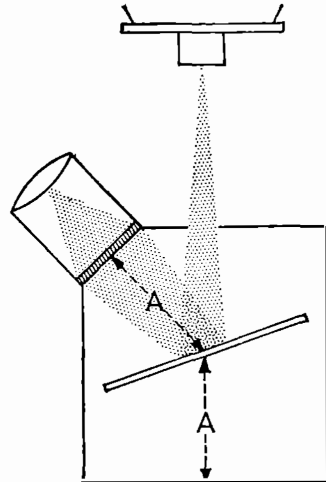
We have already discussed devices incorporated in the enlarger to facilitate focusing – including optical rangefinder methods (page 156) and automatic focusing mechanisms (page 152). There are various other aids to assessing the sharpness of the image on the baseboard.

The simplest is a magnifying glass of fairly long focus (the long focus is necessary so that the magnifier does not get in the way of the light from the enlarger lens) with which we simply observe the image projected on a sheet of white paper on the easel.

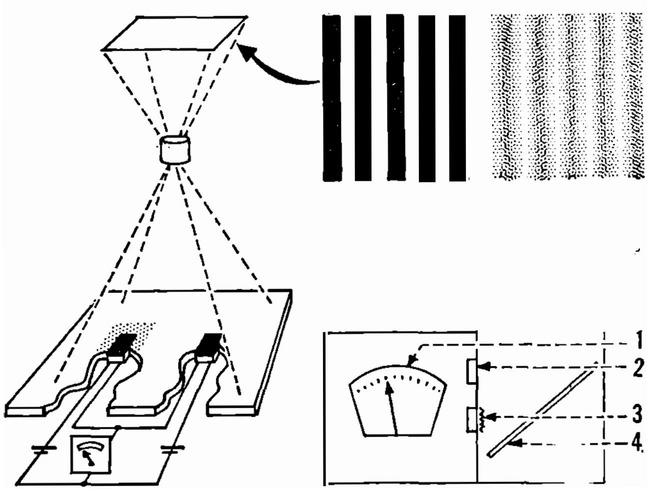
More effective are reflex focusing devices in which a mirror placed at an angle reflects light to the ground glass screen, the latter being observed through a magnifier. The distance between the projection lens and the ground glass via the mirror is identical to that from the lens to the baseboard, so that image focused on the screen must also be sharp in the print. The advantage of this arrangement is that the image appears much more brilliant when viewed by transmitted light on the screen than the reflected image on the easel. Provided that the ground glass has a fine enough grain to show the negative detail satisfactorily (this is not always the case in commercial models), such a device makes focusing very simple.

Where the ground glass grain is too coarse for detail observation, the screen can have a clear spot for the observation of an aerial image. This is sharp all the time, but if the clear spot also carries a fine hairline cross in the plane of the image area, it becomes easy to check whether the projected image is formed in the same plane as the hairlines. In case of doubt, move the eye slightly from side to side; if the image appears to move relative to the hairlines, it is not in the plane of maximum sharpness.

The effectiveness with which the image sharpness can be assessed in this way depends on the visual acuity of the user. There are also instruments which can measure sharpness



A simple focus finder consists of a mirror which reflects the light beam from the enlarger on to a ground glass screen to permit observation of the trans-illuminated image with a magnifier. The screen must be at exactly the same distance (A) from the mirror as the image plane on the baseboard.



Sharpness meters work by comparing the contrast of the sharp and unsharp image in terms of the light output from a diffused and an undiffused photo cell (*left*). A high contrast target (*upper left*) is used in the negative carrier; when unsharp it gives the most pronounced contrast loss (*upper right*). Commercial sharpness meter (*lower right*): 1, measuring instrument; 2, undiffused cell; 3, diffused cell; 4, mirror; The cells are in the equivalent focal plane. See also page 262.

directly. Such sharpness meters depend on the fact that an unsharp image has a lower edge contrast than a sharp one; its detailed brightness distribution is therefore different. While the average brightness of such an image alters only slightly when the image changes from unsharp to sharp (and that only because the lens-to-negative distance changes during focusing), photo cells under certain circumstances react differently to an image of high contrast than to the same image which has lost contrast through blurring. This is due to a so-called non-linear response of the cell and it gives its lowest reading when the image projected on the cell is sharpest.

A commercial sharpness meter based on this principle employs two similar cells which receive the projected image on the enlarger baseboard via a mirror, similar to that used in the reflex focusing device described above. One cell has a diffuser in front of it to simulate the light distribution of a completely blurred image. The current from the two cells is connected in opposition to a microammeter. This arrangement therefore cancels out the effect of image brightness variations due to the focusing travel of the lens; the meter simply indicates the difference in the two cell currents due to the relative sharpness of the image projected on the bare cell and on the diffused cell.

When the image is completely unsharp, the currents from the two cells balance and the meter gives a zero indication. As the image reaching the unprotected cell gets sharper, the current from the cell drops and the two cell circuits no longer balance. The meter needle then gives a reading, which reaches its highest point when the projected image is sharpest. To focus we therefore only have to adjust the enlarger until the meter gives its highest reading – without any visual assessment of the image at all.

This method works best if the negative itself is of high contrast. A special ultra-contrasty target negative is therefore used for focusing, and consists of a pattern of fairly fine alternating black and transparent lines or squares. When the point of maximum sharpness is obtained, this target image in the negative carrier is replaced by the negative to be enlarged. The latter must obviously be in the same plane in the carrier, and the enlarger head must not be moved during the change-over.

Enlarging Exposure Meters

When taking pictures with a camera, exposures have to be estimated or else measured with a meter. Except with an instant-picture camera which yields the results within a few seconds, it is rarely practical to make preliminary exposure tests – for the simple reason that they cannot be evaluated until much later, once the film has been processed.

Fortunately exposure estimation in the camera is comparatively easy and reliable, since all the factors on which exposure depends are known. The only exception is the brightness of the object to be photographed, which is exactly what we measure with an exposure meter. And the brightness of normal outdoor subjects under specific weather conditions and at known times of the day is also fairly predictable. This is one of the reasons why even exposure tables lead to successful results most of the time. The other reason is that the films used in the camera, especially black-and-white negative materials, have considerable exposure latitude.

In enlarging on the other hand we not only do not have this latitude, but we are dealing with a whole range of unknown factors. While we know the sensitivity of our films, we do not know the exact speed of our enlarging paper. Camera lenses can be set to exact apertures of specified light transmission; in the enlarger the required exposure depends also on the intensity of the light source, the magnification and sometimes other factors. So exposure estimation with an enlarger is hardly ever reliable. Fortunately the result – the exposed and processed print – can be inspected almost immediately and any correction applied. This is why test strips and test exposures through a density scale make sense in the darkroom – provided we can afford the time and waste a certain amount of paper to make them.

Such tests are however cumbersome, and there are more scientific methods of measuring the exposure required for a given negative and enlarging paper. To take care of the

variables in enlarging we actually require two values: the brightness of the image projected on the baseboard (and we shall consider shortly what parts of the image are significant) and the relative speed of the enlarging paper used. The light measurement can be carried out by various instruments such as photo cells and photometers; determination of the paper speed is a matter of calibration by test exposures. (But only one test is required for each paper – not for each negative or exposure.) Once we know these two values, the determination of enlarging exposures becomes as simple as measuring camera exposures.

INTEGRATED AND DETAIL READINGS

There are two ways of measuring the brightness of the projected image on the baseboard: we can measure the average light reflected from the whole image, or we can measure the brightness of selected image details. The former is the integration method, analogous to average reflected light readings with a camera exposure meter. For enlarging exposures, such integrated readings are usable only with certain qualifications, which we shall discuss more fully on page 275. However integrated measurement has the advantage that it lends itself to automatic exposure control by a photo-multiplier system, and for this reason is widely used in printing laboratories which have to maintain a high output of prints.

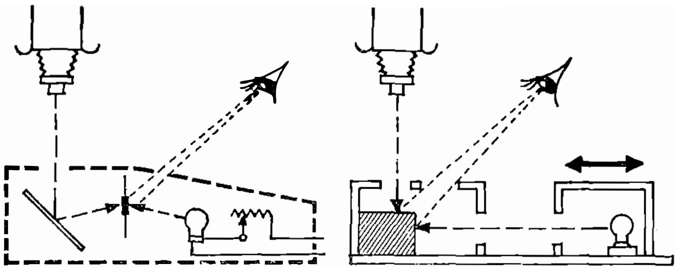
For other reasons, integrated readings are the most practical method for exposure measurement with colour negatives (page 297).

Detail readings establish the brightness of both the lightest and the darkest portions of the image projected on the baseboard. This is the most scientific way of establishing not only the correct exposure but also the contrast grade of paper required for the negative being measured.

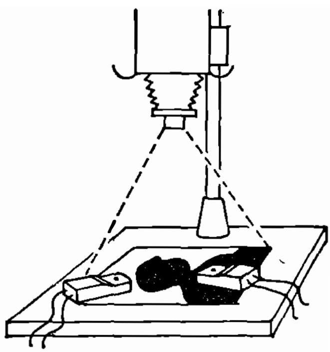
MEASUREMENT AND METHOD

The basis of all enlarging exposure meters for detail measurements is the measuring probe. This may be either a photometer or – in more modern instruments – a photo-conductive cell such as a cadmium sulphide cell.

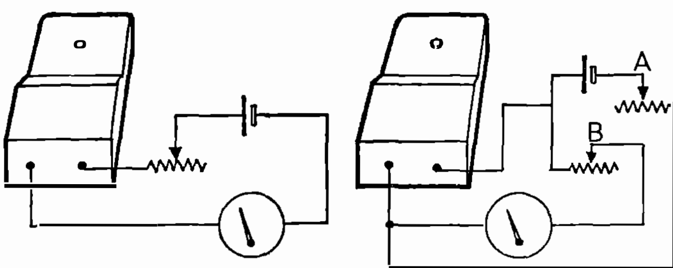
With the photometer the projected beam from the enlarger lens is reflected by a mirror on to a ground glass



In the grease spot photometer (*left*) a grease spot in a translucent screen is illuminated on the one side by the enlarger beam and on the other by a lamp of adjustable brightness. When the spot becomes invisible, the lamp adjustment gives an exposure indication. In the comparison photometer (*right*) the brightness of two sides of the comparison block is brought to a balance point by moving the lamp.



With photo cell meters different portions of the projected image are easily measured to assess contrast and exposure. Photo cell probes are more convenient for this owing to their small size.



A simple photo cell probe circuit consists of a battery, variable resistor and measuring instrument. A more elaborate circuit (*right*) uses a resistance bridge, with resistor A for calibration, and B for balance control.

screen containing at its centre a small much more heavily diffusing – or even opaque – spot. The mirror arrangement is similar to that used in a reflex focusing device (page 260). The image on the screen appears bright, but the central spot is much darker.

To measure the light intensity, a lamp of adjustable brightness (for example fed through a variable resistor) illuminates this screen and the spot from the front. When the light intensity from this lamp matches the light coming through the ground glass screen, the central spot blends into its surroundings.

Alternatively, the photometer may consist of two similar surfaces divided from each other. One surface receives the light from the image, and the other from the photometer lamp. Here again the intensity of the latter is adjusted until the brightness of the two surfaces match.

Exposure meters with photo-conductive cells are considerably more convenient than photometers, but also appreciably more expensive. The cadmium sulphide cell has two advantages:

(1) It is very small and can therefore be built into a small probe which holds the cell only a fraction of an inch above the image plane. Thus no mirror boxes are necessary, and the probe is easily moved about anywhere on the enlarger easel while connected to the measuring instrument itself which can be placed out of the way.

The cell is usually set in the centre of a white area of about 3 to 6 sq. cm or ½ to 1 square inch which shows the projected image portion being measured.

(2) The high sensitivity of the cell permits much more accurate readings at low light intensities.

The cadmium sulphide cell current can either be fed into a galvanometer to produce a pointer reading on a calibrated scale, or connected to a bridge circuit. The cell current is there matched to another adjustable current and a balance point established by a suitable indicator (for example the extinction of a small neon tube, or a magic eye or similar device). The setting of the balance control here shows the light reading.

More elaborate meter systems may use a photocell linked to a memory and computing circuit and a light-emitting diode display. Once the unit is calibrated to the paper

speed, we only place the photocell probe in the projected image area to be measured and press a button. The correct exposure time appears on the LED readout; pressing an exposure button then switches the enlarger lamp on and off for the required time.

Enlarging exposure measurement involves, as already mentioned, two operations: (1) calibration for the enlarger and paper speed used; and (2) the measurement of the lightest and darkest portions of the projected image on the baseboard to establish the paper grade and exposure time required for any negative.

Enlarging exposure meters differ primarily in the method of calibration and of relating these calibration data to the actual light reading. Such calibration can involve (a) test strips, (b) a standard negative or (c) a standard grey scale in place of the standard negative.

CALIBRATION BY TEST STRIPS

This method involves making a test strip for every make and grade of paper to be used. The test strip is prepared in a manner similar to that described on page 241, but with the following differences:

(1) The enlarger is set for its maximum magnification, with the lens stopped down to the smallest stop, but with no negative in the carrier.

(2) We shall require rather closer intervals between the exposure steps, and the scale of steps will have to be longer.

So start with 4 seconds as before, and then give succeeding steps, as the strip is progressively covered up, exposures of 5, 6, 8, 10, 12, 16, 20, 24, 32, 40, 50, 65, 80 and 100 seconds. At the same time measure the intensity of the enlarger beam, as projected on the baseboard and used for exposing the test strip, with the photometer or exposure meter. Note this reading, preferably in terms of an arithmetic value (such as exposure time in seconds) if the meter is thus calibrated. Preferably start the test with a rapid enlarging paper of normal contrast grade.

While making the test strip mark a small cross on the paper surface in pencil on a middle step – for example the one which has received an exposure of 20 seconds – for identification. Before processing mark the type of paper

used on the back of the strip, also in pencil. Process the strip in exactly the same way (for the same time and at the same temperature) as used for processing your prints later on. *This is important.*

The strip should show a scale of steps from pure white to full black. Mount it on a piece of card and write on the latter the exposure time next to each step (this is where the marked step is necessary for identification) as well as the meter reading and paper used.

At the other side of the strip mark on the card a so-called tone value against each step. This tone value is simply the meter reading divided by the exposure time in seconds for every step. So if for instance the exposures of the visible steps from lightest grey to full black run from 5 seconds to 100 seconds, and the meter reading for the light when making this test strip was 200 seconds, the tone values will run 40, 33, 25 etc. down to 3, 2·5 and 2 for the blackest step. These tone values are also a direct indication of the numerical paper sensitivity, and can be used to determine not only the exposure for printing a negative as a whole, but also for locating any specific tone on the tone scale. We shall come back to that a little later.

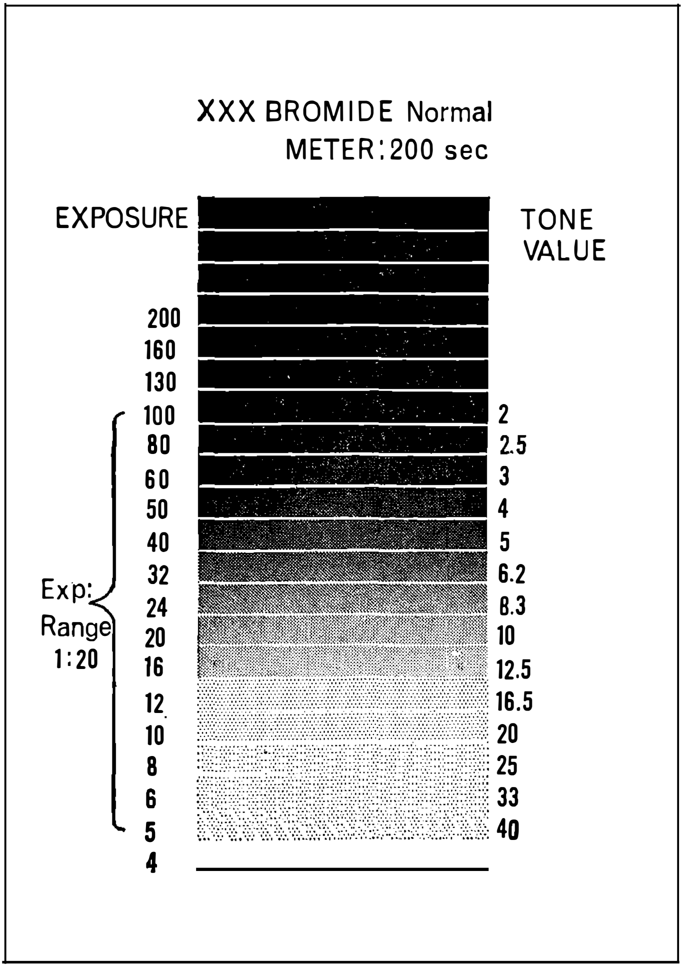
If the test strip shows only two or three light grey steps, repeat the test with the enlarger lens opened up by two stops or the enlarger set for half the magnification used before. Remember to note again the new meter reading.

Repeat this for every paper type and grade used. With the soft papers it may be necessary to extend the range of exposure times to possibly 200 or more seconds to obtain a full black (using additional exposure steps of 130, 160 and 200 seconds).

The stepped test strip also tells us immediately the exposure scale of the paper, in other words its contrast grade. For this purpose note the exposure time which the darkest step had received – in other words the first step which is indistinguishable on the strip from the next darker one.

For example if the lightest step had received an exposure of 5 seconds and the darkest step 100 seconds, the exposure range is 5:100 or 1:20. This corresponds to an average normal paper grade. Table VII on page 88 lists the exposure ranges of paper grades of the generally accepted designations. It must be stressed however that the contrast names

PAPER CALIBRATION CARD



A paper grey scale, prepared as described on page 267–268 yields a number of steps from white to black. The ratio of exposure times for the first grey and the first black steps gives the exposure range, a measure of the paper contrast grade. The meter reading divided by the tone value of any given step gives the exposure time required for a grey of that step.

are arbitrary; a normal grade of one manufacturer may well correspond to a soft grade of another. In all cases it is the exposure scale which counts.

With our set of calibration cards (i.e. the test strips stuck on cards with the data marked alongside – page 269) we can now obtain an actual value for the exposure time for any given negative with the same enlarger and measuring instrument used. The procedure is quite simple.

Arrange a negative in the enlarger to give a sharply focused projected image of the required size. Then measure the brightness of the densest highlight and of the thinnest shadow in this projected image. These readings should be in terms of exposure time on the meter scale. If the scale is not calibrated in exposure times, any other arbitrary arithmetic scale, assigned values of seconds, will do. The only condition is that the same scale shall have been used for measuring the brightness of the light on the baseboard when making the test strip.

From the ratio of the two readings establish the exposure scale of the paper grade required for the negative. Next select the calibration card of a paper of that exposure scale. Finally divide the meter reading for the densest highlight in the projected image by the tone value on the calibration card for the lightest grey, to get the correct exposure for a print on that paper. As we have by this process chosen a paper of the correct exposure scale, the deepest shadows will automatically print full black with the same exposure time.

The value of these calibration cards is however that they also permit any other negative tone to be printed to a predetermined print tone. This is useful if we want to print a negative on a more contrasty paper for better detail contrast (page 98) or distort the print tones deliberately for special effects.

To do this simply measure the brightness of the required key tone in the projected image with the meter, again in terms of an exposure time in seconds as before. Divide this value by the tone value of the print tone in which this key tone is to reproduce. That gives the actual exposure time required in seconds.

For example in a portrait negative we may want to print the shadow side of a face to record as a medium grey tone.

From the calibration card for the paper to be used we note that the grey we want has a tone value of 12·5. Measure the shadow area of the face in question in the projected image on the enlarger baseboard. Suppose this gives a reading of 50 with the exposure meter. The required exposure is then 50 divided by 12·5 = 4 seconds.

SIMPLIFIED TEST STRIPS

The test strip described on page 267 used three steps for every doubling of the exposure time. This makes for greater accuracy, but is not absolutely necessary, especially when calibrating the normal to soft paper grades. There a strip with half-step increments is quite adequate. The procedure can be further simplified by exposing the test strip underneath a step wedge. This should have a density range of at least 1·6 to 1·8, with step increases of 0·15 in density.

Such wedges are available commercially in various forms and versions. With an overall exposure of one minute the individual steps will then correspond to effective exposure times as given for "print exposure" in the table XI on page 244. The test print made in this way (without a negative in the enlarger) is again mounted on a piece of card to produce a calibration card for each paper type and grade. For softer papers a second test print will be required, giving an overall exposure time of 4 minutes. The effective print exposures will then be four times the values indicated in Table XI.

The two test pieces now form the complete calibration card. Some of the steps on the two tests will overlap: step A on the second test print will correspond to step E on the first one, B on the second print to F on the first one, and so on to step F on the second piece which corresponds to step K on the first one. G, H, I and K are the additional steps on the second piece required to cover a paper of an exposure scale of more than 1:24. The complete calibration card is then used in the same way as already described.

One important precaution with all light measurements on the enlarger easel is that no light other than from the projected image must reach the measuring probe (meter cell or photometer). While taking measurements therefore switch off all other lights in the darkroom, *including the safelight*. Any extraneous illumination reaching the meter cell would falsify its readings.

Secondly, the paper calibration should be repeated at intervals of around 6 to 9 months (for enlarging papers do change slightly in speed during storage) and whenever a new batch of paper is obtained – since there are also batch-to-batch variations in sensitivity.

CALIBRATION BY A STANDARD NEGATIVE

Many commercial enlarging exposure meters simplify calibration by incorporating calibration settings in the instrument itself. This eliminates the need for making calibrating cards and test strips for each paper, though a simple test to establish the exposure scale of a paper (for example as indicated on page 245) is still necessary.

The following description is typical of the method; the instructions issued with the individual enlarging exposure meter should be consulted for the detailed procedure.

The principle here is that a best possible print is first made from a standard negative by orthodox trial and error methods. The same negative is then measured at the identical enlarger settings (magnification, lens aperture etc.) and this measurement related to a calibration factor.

If the photo cell is connected to a balancing circuit, the balance setting itself is the calibration of the meter for the enlarger and the paper used. The measurement of the negative image can be taken either from the densest highlight (ignoring insignificant extreme densities such as catch lights or images of light sources in the picture) or from the deepest significant shadow tone. (But the method must be consistent for the standard calibration and for subsequent exposure readings.)

To print any other negative, irrespective of magnification, the projected image of the unknown negative is measured in the same way. However this time we open or close down the lens diaphragm of the enlarger until the meter indicates the same reading or balance point as with the calibrating negative. The print can then be made with the same exposure time as was used for the calibration.

Generally such meters also have a separate measuring scale to establish the density range of the negative (by measuring both the highlights and the shadows of the projected image), for selecting the correct paper grade (see also Table VII on page 88).

Different paper types and paper grades should ideally be calibrated separately, preferably with standard negatives of the appropriate density range to give best possible prints on the various paper grades. The instructions with most enlarging exposure meters however include lists of paper speeds or speed factors of commercially available enlarging papers. When changing from one type of paper to another, the ratio of the two speed values then gives an approximate guide for the correction in the exposure time required for the new print.

Exposure meters with a balancing circuit can also be designed as combined measuring instruments and exposure timers. In this case the balancing circuit is adjustable by two separate controls: a time setting and a calibration setting. The first is at the same time the exposure time selector of the timer which automatically switches the enlarger lamp on and off on pressing an operating button (page 236). The calibration control then serves to adjust the instrument for different paper speeds.

The starting point is again a standard negative and the best possible print made from it. The exposure time required for this print is set on the time control, and the calibration control adjusted to its balance point when the meter cell measures the highlight area in the projected image of the same negative. For the same paper, different maximum highlight densities of various negatives, different magnifications and different lens aperture settings are now automatically compensated by adjustment of the exposure time control to the balance point of the instrument while measuring the highest highlight of any other negative. The calibration control must remain undisturbed except for recalibration.

STEP WEDGE INSTEAD OF NEGATIVE

The choice of a standard negative for the methods just discussed is really a rather arbitrary matter. It depends on what negatives we have available, and what we judge to be "standard". An alternative way is to use a step wedge in the negative carrier of the enlarger. This wedge has to be small enough to fit into the image frame of the smallest negative to be used (for example 24 × 36 mm) and must have the steps readily identifiable, for instance by code letters. Actual density values are less useful, firstly because the readings

themselves are comparative, and secondly because enlargers differ in their Callier factor (page 118). The step differences must however be constant and preferably not more than 0·1 per step. Such a density wedge is specially produced for use with the *Fotoval* enlarging exposure meter.

Calibration now involves three operations, and printing two further steps.

(1) With the enlarger set to a high magnification and the wedge in the negative carrier, the meter probe is used to measure the brightness of the lightest step of the wedge negative. It is most convenient to relate this to a zero point on the meter scale, for example by adjusting the lens aperture. Then the other steps in the projected image are measured one by one. The readings of these steps are noted; they characterise the calibration of the enlarger. (It is enough to know where the readings come on the scale; the meaning of the scale values is not important.)

(2) The entire wedge is projected on a test piece of the paper to be calibrated and exposed for the correct time (by trial and error) to give a just visible separation between the blacks corresponding to the two thinnest steps of the wedge. The enlarger lens aperture for this exposure is adjusted, so that a meter probe reading of the thinnest wedge step again gives the zero reference reading (in fact a reading at the high end of the scale) on the meter. Where the meter has several sensitivity ranges, the range is chosen according to the relative enlarging paper speed.

This exposure time – for the test print of just visible separation between the two blackest tones – becomes the standard exposure time for all negatives on that paper.

(3) On the developed test print the lightest visible step (highest wedge density recorded on the paper) specifies the exposure range of that paper.

(4) To print any negative it is now only necessary to measure the thinnest area in the projected image with the meter probe, and adjust the lens aperture until the meter needle is at the zero or key reference setting. The grade of the paper required is obtained by measuring the densest highlight in the projected image and noting which wedge reading – as carried out in calibration step (1) above – this corresponds to. For instance the reading for the densest highlight may be the same as that for a field X in calibration

step (1) above. So we choose a paper grade whose test print in calibration step (2) above showed field X as the lightest grey step.

(5) The exposure time required is the same as for the calibration test print of the paper selected under (4) above. The lens aperture still remains at the setting required to bring the meter reading for the thinnest shadow – as in step (4) above – to the key reference point on the scale.

If a negative is too dense or too thin – or the magnification too high or too low – to obtain a zero reference reading for the thinnest shadow, a different sensitivity range of the meter can be chosen and the exposure multiplied by an appropriate factor.

MEASURING BY INTEGRATION

Reading selected image portions on the baseboard of the enlarger is necessarily a slow business, and unsuitable for any form of automation: we must select the image area we want to base our exposure on, move the meter probe into the appropriate position and take the reading itself. No automatic system so far devised can replace these manual steps.

The integration method of exposure measurement is based on taking in the average light projected on a substantial proportion of the image area. Such a measurement can be taken not only automatically, but even during the enlarging exposure. In this case a photo multiplier cell can switch off the enlarger when the right amount of light has reached the paper – obviously a very much quicker way of working.

Such methods are therefore used in commercial printing laboratories where output is the main consideration. The automatic system remains under the control of a trained operator who can make the necessary overriding allowances for the quite appreciable range of circumstances where integrating readings become unreliable. The main reason why it may still often be rational to work in this way is that the equipment takes care of virtually the whole of the manipulative side and does it very much more quickly; the operator only has to make instant decisions when to use overriding control – and press an appropriate button.

What then are the problems of integrating readings?

As with a camera exposure meter measuring the light reflected from the subject, certain assumptions have to be made about the tone distribution of the "subject", i.e. the negative in the enlarger. The main one is that the average reading is proportional to the density of a closely specifiable medium tone of the negative. This is only true if the negative tones are evenly distributed above and below this mid-point – in densities as well as in relative areas.

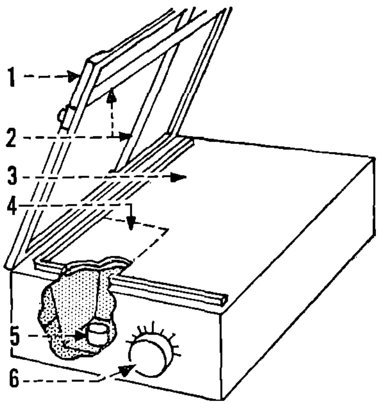
Since it is difficult to establish just what is the mid-point density of the negative (except in a roundabout way) the methods of exposure measurement so far described are based on assessing either the shadow or the highlight density. (Provided the correct paper grade has been chosen for the print, it does not matter which end of the scale is used for measurement.) So if two negatives have equally dense highlights, they should require the same enlarging exposure. But if in one negative the highlight areas occupy 50 per cent of the total negative area, and in another case only 20 per cent, the average light coming through the two negatives must be very different. An integrating reading would therefore lead to appreciably different exposures for the two, and at least one—if not both—would be wrong.

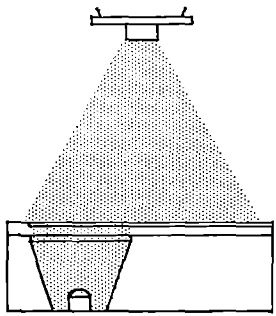
So with an integrating method, the user has to operate an overriding correction according to the appearance of the negative. If it has comparatively large shadow and small highlight areas, the average reading will indicate too short an exposure; so the exposure must be increased above what the reading indicates. Conversely, a negative with large highlight areas needs a reducing correction, when the printing exposure is determined in this way.

Further, an integrating method provides no information about the density range of the negative – i.e. the contrast grade of the printing paper required. This again is left to the operator to judge. He may be able to work fast because he only has to press buttons; but no automatic system can make these particular decisions for him. Without this control there will always be a certain proportion of wastage.

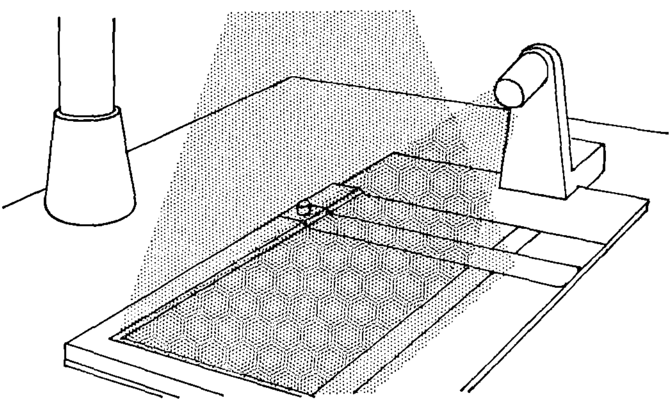
Where a range of paper grades of one manufacturer is matched for speed (page 115) in the mid-point of the tone range, this is particularly useful with integrated readings, and reduces the need for resetting the paper speed.

The simplest way of taking an integrated reading is to





A photo multiplier cell in the masking frame measures the light coming through the paper and through a translucent panel underneath the paper. When enough light has reached the photo cell, it automatically switches off the enlarger light. 1, masking frame; 2, masking strips; 3, focusing surface; 4, measuring area (a small translucent panel in the focusing surface); 5, photo multiplier cell; 6, calibration adjustment.



An alternative way is to measure the light reflected from the enlarging paper by means of a photo multiplier cell attached to the masking frame. Like the previous method, this is an integrated reading and is subject to certain sources of error.

place a sheet of ground glass immediately below the enlarger lens. The position of this glass must be fixed for all readings. With a standard negative in the enlarger (i.e. a negative for which the correct exposure time with a particular paper has been determined beforehand by tests) a reading is taken with the cell of an ordinary enlarging exposure meter on the baseboard. To find the exposure for an unknown negative, this is placed in the negative carrier, the ground glass sheet mounted in front of the lens, and the lens aperture adjusted until the exposure meter again gives the same reading. The same exposure time as used for the standard negative should then give a correctly exposed print with the unknown negative – subject to the overriding corrections discussed before. The exposure measurement however allows automatically for different magnifications and different *average* negative densities.

Some enlargers, especially for colour (page 302), have exposure meter cells built into the lens panel behind the lens. These cells take in the average light passing through the negative, and provide similar integrating readings. However in this case an allowance for the magnification is also necessary since the cell measures the light before it reaches the enlarger lens, and not on the baseboard.

Integrating readings are even possible with a camera exposure meter placed immediately below the enlarger lens. Here again the result requires correction for the final magnification of the print.

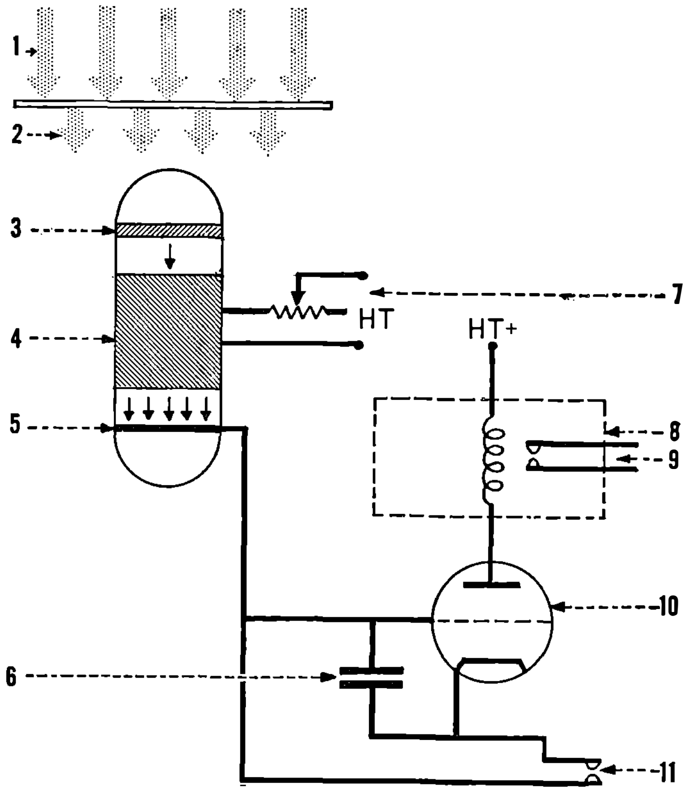
Two other systems of integrated measurement are:

(a) Measurement of the light coming through the enlarging paper. This is utilised in masking frames with built-in exposure control.
(b) Measurement of the light reflected from the enlarging paper.

AUTOMATIC MASKING FRAMES

In principle these consist of a masking frame with a translucent base surface. A photo cell underneath this surface measures the light passing through the printing paper over a fixed area of the printing surface. This fixed area must always be smaller than the total print size, to ensure that

PHOTO MULTIPLIER CELL FOR EXPOSURE CONTROL



Pressing the exposure button 11 discharges the capacitor 6 and causes the valve 10 to conduct current. This energises the relay 8 the contacts of which (9) close and switch on the enlarger lamp to start the exposure.

Light 2 of the projected image 1 passing through the printing paper, reaches the photo cathode 3 of the photo multiplier cell. The current produced (according to the light intensity) passes through the amplifying system 4. The amplified current 5 gradually charges the capacitor 6 connected to the grid of the valve 10. As the capacitor charge reaches a certain value the valve current drops until it can no longer hold the relay 8. At this point the contacts 9 open, switching off the enlarger lamp and terminating the exposure. The lamp remains off until the exposure button 11 is again pressed and released. A basic sensitivity adjustment in the form of a potentiometer 7 is usually connected to the photo multiplier system.

Practical units contain additional components, and usually replace the valve circuit and relay by a transistor system.

the meter can measure the average light – intensity per standard area – coming through the paper.

The calibration and measurement are in principle similar to the method with a diffusing screen underneath the enlarger lens. The calibration must however take into account not only the paper speed, but also its base thickness. For instance single-weight papers will pass through a larger proportion of the light falling on them than double-weight papers. And the transmission also varies with papers of different manufacture.

This type of masking frame usually incorporates automatic exposure control with an electronic timing circuit. The cell underneath the paper and translucent surface of the masking frame is in this case a photo multiplier which is connected to a circuit measuring light quantity rather than light intensity. The multiplier controls the timer circuit and switches off the enlarger lamp when enough light has reached the paper for a correctly exposed print.

A typical circuit consists of a photo element which produces a current when light falls on it. This current is amplified to enable it to operate the timing circuit. The photo multiplier current charges up a capacitor connected to transistors, thyristors and other semi-conductor elements. At the start of the exposure, the current to the enlarger lamp is switched on through this transistor circuit. As the capacitor reaches a certain predetermined charge during the course of the exposure, this charge – applied to one of the transistors or thyristor systems – cuts off the current to the enlarger lamp and so terminates the exposure. Older circuits of this type used valves and relays for the same purpose.

This set-up with transistor switching is thus similar in principle to one form of an electronic timer (page 236). Instead of being controlled by a variable resistor with scale settings in exposure times, the photo multiplier here directly controls the timer operation. If the light reaching the photo multiplier is weak, the capacitor takes longer to charge and the relay switches off the enlarger lamp later, resulting in a longer exposure. Conversely, a higher light intensity – from a thinner negative, lower magnification or larger lens aperture – leads to a shorter exposure.

The calibration for paper characteristics (sensitivity and transmission of the paper base) may be done in various ways

– for instance by a potentiometer which alters the amplification of the photo multiplier system, or by a variable resistor in series with the capacitor circuit. These elements can also be used for the overriding control where individual negatives have a non-average tone distribution.

Exposure control by reflection measurement is similar in principle, but the photo multiplier cell here receives the light reflected from the surface of the enlarging paper during the exposure. Such an arrangement involves numerous potential sources of error, arising from the positioning of the photo multiplier cell, the reflectivity of different paper surfaces and even the degree of reflection at different magnifications where the light reaches the paper area "seen" by the photo multiplier cell at different angles. Reflection meters of this kind are however fairly easy to use provided the conditions and calibration are reasonably standardised – for instance locating the cell in the same way every time etc.

USING PHOTOGRAPHIC EXPOSURE METERS

While older selenium cell exposure meters are not sensitive enough for the brightness levels of the negative image projected on an enlarger easel, the best of the present day cadmium sulphide meters are adequate for the purpose. As the position of the cell is impossible for using the instrument on an enlarger baseboard, a few more advanced cadmium sulphide camera meters have plug-in probes or reflecting attachments to turn the meter into a baseboard probe.

To adapt the camera-orientated exposure scales to enlarging use, set the enlarger to its lowest normally used magnification (e.g. 2 diameters) and measure the light coming through to the baseboard with no negative in the carrier and with the enlarger lens fully open. Adjust the aperture and film speed settings *on the meter* until this reading corresponds to an exposure time (again on the scale) somewhere between 1/10 and 1 second. Note the film speed setting and always use the same aperture mark or number for reading off the exposure time on the shutter speed scale. The latter then provides straightforward readings which can be converted into enlarging exposures by a simple factor – established by the same calibration procedures as discussed before.

Colour Enlarging

We have on page 200 already briefly stated the principles of three exposure (tricolour) and single-exposure (white light) colour printing. In the former method the blue-green producing layer of the colour paper (which is sensitive only to red light) is printed through a red filter. The magenta-forming layer which is sensitive only to green light, is printed by a further exposure through a green filter, and the yellow-forming layer which is sensitive only to blue light, through a blue filter. The relationship between the filters and layers is therefore as follows:

(a) The red filter exposure controls the cyan image;
(b) The green filter exposure controls the magenta image;
(c) The blue filter exposure controls the yellow image.

Each of the three separate images building up the final colour picture can therefore easily be controlled by the length of these three exposures.

For instance, the longer the red filter exposure, the stronger the image will be in the red-sensitive layer – i.e. the more cyan there will be in the picture. Conversely, reducing the exposure through the red filter decreases the cyan component (i.e. leaves the magenta and yellow more dominant), so making the picture more reddish. In the same way, increasing the green filter exposure increases the green content by reducing the magenta density of the print (i.e. proportionately increasing cyan and yellow).

COMPARATIVE MERITS OF PRINTING METHODS

The main practical advantage of printing with three filters in this way is that these three filters – plus some means of holding them in front of the enlarger lens (such as a filter turret – page 202) are the only items required for colour printing. Therefore any black-and-white enlarger is easily adaptable for this purpose. The filters are varnished gelatine

or acetate film, comparatively inexpensive and easily replaced if they should get damaged.

The ratio of the three separate exposures is also individually adjustable within very wide limits to provide almost any degree of colour control in any direction. With white-light printing a similar degree of correction possibilities would require a large number of filters.

Further, the three-exposure method lends itself easily to automatic control not only of exposure time but also of colour balance: the three exposures can be individually monitored by photo multiplier cells which terminate each exposure when sufficient red, green or blue light respectively has reached the colour paper. The three-exposure method is therefore more widely used for automatic colour printing.

Tricolour printing can produce slightly higher colour saturation and better contrast in the final picture than white light printing. This is because the three filters ensure that each colour component is recorded only in the paper layer sensitive to it. With white light printing there may be a certain overlapping of effects leading to slightly reduced colour saturation, though in practice this is rarely sufficiently serious.

Three-exposure printing has two main and one minor drawbacks. Firstly, no part of the enlarger set-up – other than the filters – must move between the three exposures. The risk of unsharpness due to vibration is increased threefold, especially since manual changing of the filters in a slide or turret also tends to shake the enlarger.

Secondly, local control such as shading (page 412) would need equal treatment during all three exposures. This is virtually impossible to match accurately.

Finally, the exposure sequence is rather long, a drawback when an appreciable number of identical or very similar prints is to be made. There is however one tricolour method with high-density subtractive filters (page 316) in which the three exposures can take place more or less simultaneously.

WHITE LIGHT PRINTING

When cyan, magenta and yellow filters are used to modify the colour of the enlarging light during a single exposure the first requirement is an appreciable number of filters to provide a reasonable range of colour adjustment. Each of the

three colours is therefore supplied in a range of six or more densities, e.g.:

0·05, 0·10, 0·20, 0·30, 0·40, 0·50 etc.

With some makes the range of filters goes to a density of 1·0, with others higher densities are obtained by combining two (or very rarely three) filters of the same colour. But the need for densities higher than 1·0 is rare.

The exposure depends on the density of the filters which affect the three layers as follows:

(a) The yellow filter controls the yellow image;
(b) The magenta filter controls the magenta image;
(c) The cyan filter controls the cyan image.

By increasing the density, the exposure of the equivalent layer is reduced. Thus a denser yellow filter during the exposure decreases the density of the image in the blue sensitive layer, i.e. it decreases the yellow component of the picture and thus in effect increases the blueness of the image. The magenta and cyan filters act in an analogous way.

Things become involved if it is necessary to increase the exposure in one or two of the three images. This is only possible by holding back the other two images. For example, if the magenta image has to be strengthened, we need more exposure for the green sensitive layer of the colour paper, without giving more to the other two layers. Hence yellow and cyan filters of the necessary density have to be chosen. These hold back the exposure of the blue- and red-sensitive layers respectively. But since they both pass green light, the green-sensitive layer receives the necessary extra exposure to produce a stronger magenta image.

The main advantage of white-light printing is that as filters of different colours can be used together, the print is made by a single exposure. Therefore local control by shading is straightforward and comparatively easy. On the other hand, the assessment of the necessary filter and colour densities is somewhat more complicated than with three-exposure printing, and must always be a separate operation before the actual exposure. When using an enlarger with a filter drawer the required sets of filters also become expensive. Enlargers with colour mixing heads (page 306, 309) achieve colour control in a more convenient way; for the moment however we shall examine the principle in terms of separate filter packs.

FILTERS AND FILTER CODING

The filters for tri-colour printing are so-called separation filters of high density which pass virtually only light of their own colour and hold back all light of the other two colours. They are produced by most photographic manufacturers, and it is generally best to use the filter set recommended by the sponsors of the particular colour print employed. It is however usually permissible to use a filter set of one make with a colour paper of another, subject to a preliminary test to see that each filter exposes only one layer of the colour paper (page 287). Sometimes the blue filter passes some deep red or infra-red radiation, in which case it may need combining with an infra-red absorbing filter. Better still is the use of such an infra-red filter in the enlarger itself, for example above the condensers. There it also protects the colour negative against excessive heat.

Filter sets for white light printing are also offered by the manufacturers of various colour papers. They may be gelatine foil, used by itself or mounted between glass, or acetate film. The latter is more robust than gelatine foil and also less expensive. Since the filters are placed in the enlarger between the negative and the light source, flaws, fingermarks etc. do not reproduce on the colour print. But these filters should still be handled with care.

There are two ways of coding filter colours. The first, widely used in Britain and the U.S.A., indicates the filter density (multiplied by 10) by a number and the colour by a letter – Y, M and C for yellow, magenta and cyan. Thus 20Y indicates a yellow filter with a density (to blue light) of 0·20. Similarly a 05M filter is magenta with a density (to green light) of 0·05. When two filter colours are combined, the two designations are joined by a + sign – e.g. 21Y + 05M.

The six figure notation used in Europe assigns six numbers (in three groups of two) to the yellow, magenta and cyan densities in this order. In this notation a 20Y filter would be 20 00 00, a 05M filter would be 00 05 00. To include in this notation a filter density of 1·0, this receives the designation 99 – e.g. 00 00 99 for a 1·0 density cyan filter. Filter combinations are expressed by the same notation: thus 20Y + 05M becomes 20 05 00.

GRADING

As in black-and-white enlarging, judgment of the correct exposure for a colour print needs some skill and experience. In colour the procedure is however more complicated, as the picture is built up from three separate images, each of which must be correctly exposed. Our aim is a print of good colour balance, and this term requires some explanation.

Let us consider first the colour negative. The manufacturer supplies the photographer with a material which is accurately adjusted in colour balance. But he can naturally do no more than balance the emulsion to a definite colour temperature range, e.g. 5700 to 6000 K for daylight films, or 3000 to 3400 K for artificial light type films. On the other hand, the colour temperature of daylight fluctuates considerably and the colour balance of the negatives can show marked variations depending on whether they were taken in the morning, midday or evening sunlight – and on the combination of light from the sun and blue sky, overcast sky etc. And if a so-called "universal" negative colour film is used for exposures by daylight, flash and artificial light, each negative will have different proportions of the three component images making up its colour image.

Yet in the print we expect to see a rendering of the original subject which looks "right" – irrespective of the widely varying conditions under which the negatives may have been exposed. So the negatives themselves require greater or lesser correction in printing.

This is done as outlined above by the use of tri-colour or subtractive filters in printing. The method takes care not only of differences in the colour balance of the negatives, but also of all other factors influencing the colour balance of the print – such as variations between brands and even batches of positive materials, colour temperatures of light sources used in printing, the influence of the optical system of the enlarger etc.

The correct visual assessment of colour negatives is difficult even for an experienced operator, especially when the negative has an orange tinted masking image (page 72). Therefore preliminary tests are invariably necessary. The simplest methods are based on the stripwise exposure of a piece of colour paper – like test strips in black-and-white enlarging, but with the filtering taken into account.

More advanced methods (page 264) involve the measurement of selected areas of the image projected on the baseboard, again similar to black-and-white exposure measurement. Here however the colour components of the image must also be measured. We shall come back to this on page 293.

TEST STRIPS FOR TRICOLOUR PRINTING

For this method we insert the colour negative in the enlarger, focus and adjust the image in the usual way for the required print size. A small strip of the colour paper is then placed on the easel of the enlarger and given a range of exposures in steps through one of the colour filters.

The exposure steps can be obtained in the same way as described on page 242 for a black-and-white test strip. The strip will therefore have effective exposure steps of 4, 6, 8, 12, 16 and 24 seconds. This procedure is carried out with all three filters, giving separate strips exposed through the red, green and blue filter respectively.

The three steps are then processed together and will yield three coloured strips in varying densities (cyan, magenta and yellow). From these three strips the correct density can be judged for each colour, and therefore the exposure needed to obtain this density. Table XV below gives some guidance to judging the correct densities on each strip:

XV – SUBJECT TONE VALUE ON COLOUR STRIPS

	Tone Value on Colour Strip		
Subject Tone	*Cyan Strip*	*Magenta Strip*	*Yellow Strip*
Flesh tone	Light	Medium	Medium
Sky	Heavy	Medium	Light
Sea	Heavy	Heavy	Medium
Grass or foliage	Heavy	Light/medium	Medium/heavy
Grey	Medium	Medium	Medium
Brickwork	Light	Medium	Medium

At this point it is also useful to check that the colours are pure. In other words, neither the yellow nor the magenta strip should have any tinge of blue or green in it (the cyan strip will probably be pure anyway). If the magenta or

yellow are not pure, this means that the green or blue filters (or both) transmit some light to which paper layers other than the green or blue-sensitive ones respectively respond. Most likely is the transmission of unwanted red or deep red by the blue filter – hence the desirability for an infra-red absorbing filter in the enlarger (page 285).

The next step is to obtain a print with all three colours on the same sheet of paper. This is done by giving three exposures through the filters on the same sheet of colour paper, the exposures being those estimated from the test strips. The actual step chosen for each exposure should be the one immediately *below* (i.e. lighter in density) to the one judged as being best exposed.

It is advisable to do this combined print as a test on a small piece of paper first, and then modify the individual exposures as required.

If the colour balance is satisfactory, but the print as a whole is too dense or too light, all three exposures are adjusted in the same proportion. Thus if a print exposed for 9, 15 and 20 seconds respectively through the red, green and blue filters needs one-third more exposure, the new exposures will be 12, 20 and 27 seconds.

XVI – TRICOLOUR PRINTING CORRECTIONS

If print is	*More Exposure is Needed Through*	*Or less Exposure Through*
Too magenta	Red and blue filters	Green filter
Too red	Red filter	Blue and green filters
Too orange	Red and green filters*	Blue and green filters*
Too yellow	Red and green filters	Blue filter
Too yellow-green	Green and red filters*	Blue and red filters*
Too green	Green filter	Blue and red filters
Too blue-green	Green and blue filters	Red filter
Too blue	Blue filter	Red and green filters
Too purple	Blue and red filters*	Green and red filters*

* In these cases the two exposures need adjustment in different proportions; this is why the same filter colour figures in both the columns for increased and decreased exposure. For instance an excessive orange cast can be reduced by increasing the red filter exposure considerably and slightly increasing the green filter exposure. If however the blue filter exposure is decreased instead, the green filter exposure must also be reduced—though to a lesser degree.

If the colour balance is unsatisfactory, the proportions need adjustment. This can be done by increasing or decreasing the exposure through one or two of the three filters, as shown in Table XVI on page 288. The total exposure through the three filters should however remain the same if the density was already correct. After adjustment of the proportions therefore all three exposures have to be increased or decreased in the same ratio to obtain the previous total.

PROGRESSIVE TEST STRIPS

An alternative way is to build up test strips progressively. This is a procedure:

1. Make a test strip through the red printing filter in the way described before. After processing examine the strip to find the best exposed step. The image is only cyan, and the correct step should be rather weaker than a corresponding test step for black-and-white enlarging, but still show full detail. Make a note of the exposure time – for example 12 seconds.
2. Make a second test strip giving it the red filter exposure previously found correct (12 seconds) and then a stepped series of green filter exposures. Process the print and select the best step for blue rendering, without excess magenta or cyan. Once more note the correct exposure – for example 6 seconds.
3. Make a third test strip giving it 12 seconds through the red filter, 6 seconds through the green filter and a stepped series of exposures through the blue filter. After processing check the yellow content of the different steps. (A neutral area is particularly helpful to see whether there is neither too much yellow nor too much blue.) The exposure for the correct step is again noted.
4. Make a final print, using the three exposures obtained from steps 1 to 3.

If at any stage no correct step can be seen, repeat the test up to that stage but use an appropriately greater or smaller exposure through that filter. Thus if all the steps at stage 2 above are too cyan, make another strip with 12 seconds through the red filter and a stepped series through the green filter starting the first step with 4 times more exposure than before.

With this method of filter correction a first test strip is made in the same way as described on page 242 for black-and-white prints, without any correction filter. After processing, one step on the strip should be of approximately the correct density. If necessary, a further strip may be made adjusting the overall exposures by a given factor (if the whole strip was too light or too dark), and an additional test may also be desirable with intermediate exposures between a slightly too light and slightly too dark step to pinpoint the correct exposure more accurately.

If the test strip also showed incorrect colour balance (as the first step is most likely to do) yellow, magenta or cyan filters of the appropriate density – or a combination of two colours – are inserted in the filter drawer of the enlarger. The required correction can be ascertained from Table XVII below.

A further test will show whether the filter correction was adequate or not. It may then be necessary to increase the density of one or two filter colours, or reduce the density of some filter colours already present. These corrections are shown in the last column of Table XVII.

XVII – WHITE-LIGHT PRINTING CORRECTIONS

If print is	*Add Filter Density (at first or second correction)*	*Or Subtract Filter Density (at second correction only)*
Too magenta	Magenta	Yellow + cyan
Too red	Yellow + magenta	Cyan
Too orange	Yellow + magenta*	Cyan + magenta*
Too yellow	Yellow	Cyan + magenta
Too yellow-green	Yellow + cyan*	Magenta + cyan*
Too green	Yellow + cyan	Magenta
Too blue-green	Cyan	Magenta + yellow
Too blue	Magenta + cyan	Yellow
Too purple	Magenta + cyan*	Yellow + cyan*

* In these cases the required densities of the two filter colours are different, the first colour shown requiring the higher density. Thus if the print is too orange, we can either add a medium yellow and a slight magenta density to the filter pack, or appreciably reduce the cyan density and slightly reduce the magenta density if filters of both these colours are already present in the pack.

The filter density change depends on how badly the print is out of balance. A slight overall tint of one colour will require a filter change corresponding to a density of 0·05 or 0·10 (e.g. addition of a 05Y or 10Y filter if the print is slightly too yellow). For a strong excess, where one colour is almost masking the others, a density change of 0·40 or more may be necessary.

The filters used have their own factors, requiring exposure increases whenever a filter is added (or the density of an existing filter changed for a higher one) – and a decrease whenever the filter densities are reduced. The factors depend on the actual filters; thus the magenta filter densities usually have higher factors than either cyan or yellow filters of corresponding density. Generally the factors for the yellow filters can be ignored, as can a 0·05 density change in any filter. For other changes check the manufacturer's recommendation for the filter (with a given colour paper and enlarger).

Since filters (especially glass bound ones) lead to some light loss due to reflection, scattering etc., it is best to keep the actual number of filters in a pack constant. A pack of four filters is adequate for most purposes, permitting the combination of two filters of two colours to obtain high correction densities. If a pack requires fewer than four filters, plain glasses (dummy filters) can be inserted instead to keep the number of elements and air/glass surfaces in the pack constant.

Normally there should not be filters of all three colours present in the enlarger at the same time. If this state of affairs does arise, take out the colour of the lowest filter density, and subtract the equivalent density from the other two colours. For example if a pack after two corrections leads to a combination 30Y + 40M + 10C, remove the 10C filter and reduce the yellow and magenta by a density of 0·1 in each case. Thus the final pack would then be 20Y + 30M. The 10C + 10Y + 10M removed cancel each other out in terms of colour effect and are equivalent to neutral grey.

ENLARGER AND PAPER CALIBRATION

With certain enlargers and certain colour papers we may find that every print requires a certain minimum basic filtra-

tion. For example the filter pack may practically every time contain a minimum of 20C + 10M. If experience shows such a basic filtration to be required, this can serve as a starting point for the first test strip. It has the advantage that we have to judge much smaller – and hence more accurately estimated – colour corrections.

Such a basic filtration may be necessary with integrally masked colour negatives (with their apparent overall orange tint) when printed on colour papers designed for use with unmasked negatives.

Some manufacturers recommend a basic filtering correction for each batch of paper. This represents the degree to which the inherent colour balance of the paper deviates from the manufacturer's standard value. When buying a new batch of paper, such basic corrections should therefore be compared and applied to the basic filtering.

These corrections are even more important when a negative is known to give a good print with a particular filter combination on a given paper. If a new batch of paper has a basic correction of for instance +10M, the filter pack to print the same negative on the new batch of paper would have to be increased by 10M (or reduced by 10Y + 10C).

KEEPING NOTES

With all tests for colour printing, detailed notes are important of the correction filters and exposures employed. Since the processing of even a colour test strip takes some time, it is easy to forget the relevant exposure data by the time the processed strips or test prints are compared and evaluated.

In the first instance the data should be written in pencil on the back of each test or print. For tricolour printing it is sufficient to write down the exposure times through each filter – for example 10R – 15G – 12B, to represent 10 seconds through the red, 15 seconds through the green and 12 seconds through the blue filter. For white-light printing note down the filter combination plus the exposure time e.g. 15Y + 25M — 20 seconds.

Once the final filter combination and exposure for a print has been established, it is useful to note these data down in a separate book against the negative being printed. This is not only useful for future reference if further prints from the

same negative are to be made, but also helps to establish any corrections required if such prints are to be made on a new batch of paper.

Finally, such notes also give a guide to the necessary printing data for other negatives of a similar character. Thus negatives of the same subject exposed on the same film often can be enlarged with the same exposure times and/or filtering or at the most with minor corrections once the data are known for one negative in a series.

EXPOSURE METERS FOR COLOUR PRINTING

Exposure meters using a photo cell probe (page 266) can be used to measure the densities of selected portions of the image projected on the enlarger baseboard, in order to establish both the colour filtering and the exposures required. This invariably needs calibration for the enlarger and the colour paper being used, and is carried out with the aid of a standard negative. The colour balance correction is obtained by measuring specific image areas three times through a red, green and blue filter in succession over the photo cell probe. For white-light printing an additional reading without a filter establishes the actual exposure required.

The main problem in colour readings is the selection of the appropriate image detail on the enlarger easel. With a black-and-white enlargement we are concerned only with actual density, so it is an easy matter to select the lightest and darkest portions of the projected image. In colour printing we not only have to measure the red, green and blue components of the light in a particular image area, but must also know the colour value which this image area should have in the finished print. This is particularly difficult, if we do not know the original colour of the corresponding subject detail, even if we can identify the probable general colour of that detail. Thus it is almost impossible to tell from a negative whether a dress worn by a model should be red, orange, crimson etc. – yet the filtering to obtain a particular reproduction will also affect the overall colour balance of the print. Similarly, the choice of foliage or blue sky is equally indeterminate since these hues are subject to wide variations.

In practice two types of subject tone are chosen for such comparison measurements: a flesh tint and a neutral grey.

Flesh tints also vary from person to person, but most people have a fairly fixed idea of what a flesh tone should look like. Provided the reproduction of such a flesh tint in a print looks right (irrespective of whether it is really correct for the person depicted) we are prepared to accept considerably larger departures from true colour rendering in other tones and hues.

Colour memory plays a considerable part in our evaluation of colour pictures, especially when the original subject is not available for direct comparison. A flesh tone measurement therefore provides a workable compromise and also has the advantage that many photographs show people in some form or other and therefore contain a notional flesh tone. (We are at the moment assuming a European or Caucasian flesh tone; the skin tint of non-Caucasian races would require a different evaluation. However, slight colour casts are much more visible in the reproduction of a pale European flesh tint than in for instance a dark African skin.)

The second possibility is to select a neutral grey – provided the original subject is known to contain such a grey. This is not fully reliable, because not all colour papers yield their best overall compromise in colour rendering when the greys are absolutely neutral. But owing to the shortcomings of the dyes used in colour materials it is practically never possible to reproduce all colours correctly at the same time. And colour casts in neutral tones – white and pale greys especially – are generally most readily noticed in a print.

Another difficulty with neutral reference tones is that a colour we believe to be neutral in the original subject very rarely is so. Frequently such tones are tinted by reflections from other subject areas. Thus snow shadows may be blue by reflection of light from the sky, though we remember them as neutral grey; a grey wall may have a greenish tinge from light reflected by an adjacent lawn, and so on. Printing such tones to reproduce as neutral in a colour print would therefore falsify again the other colours in the picture. Once more we are handicapped by not having the original subject available for comparison when we evaluate the colour print.

One solution to this problem, frequently adopted in professional studio photography, is the inclusion of a standard reference object in the picture. This may be a chart contain-

ing large patches of white, mid-grey and black plus selected colour tones. In the studio (sometimes even outdoor) set-up such a chart is located near the edge of the image area, on a part of the negative which will not be included in the enlargement, but is available for density measurement on the enlarger baseboard. But if we have no such standard grey tone in the picture, we have to fall back on using a flesh tint as a reference colour.

SUBTRACTIVE COLOUR ANALYSIS

The first step in establishing exposures by detailed colour measurement is to make a test print – by trial and error – from a standard negative at a given degree of enlargement and lens aperture setting. The selected face or other flesh tint is then measured on the baseboard – with the same enlarger setting – through a red, a green and a blue filter in turn over the meter probe. These readings are noted, and form a standard calibration for the particular brand of negative colour film and of the colour paper used. As additional reference, it is useful also to measure a blue sky tone, green grass and a grey area (if available) in the standard negative in the same way – bearing in mind the variations to which these subject tones are liable (page 294).

When printing an unknown negative (taken on the same type of film) these are the steps for determining the filtration with the subtractive or white-light printing method:

1. Place the negative in the enlarger together with the filter pack used for the standard negative.

2. Select the probe filter *complementary to the colour not contained* in the filter pack over the meter probe. For example if the filter pack was 20Y + 30M, cyan is missing from the pack. So start with its complementary, i.e. the red filter.

3. Select a subject tone similar to that used for measurement in the standard negative (e.g. again a flesh tint).

4. With the red filter over the meter probe measure the brightness of this subject tone on the enlarger baseboard. Adjust either the lens aperture or the exposure time setting of the meter until the red filter reading is the same as it was for the standard negative of a comparable subject area.

5. Place the green filter over the meter probe and measure the same area. This time increase or decrease the density of

the magenta filtration in the pack until the probe reading is again the same as it was with the standard negative through the green filter.

6. Repeat through the blue filter and adjust the yellow filter pack in the enlarger.

7. An exposure with the time used for the standard negative (if the lens aperture was adjusted for the probe readings) or with the exposure indicated during the first probe reading (No. 4 above) should then yield a correctly exposed and correctly balanced print.

ADDITIVE COLOUR ANALYSIS

For tricolour printing the calibration with the standard negative must establish the required exposure times through each of the three printing filters. The probe filters used when evaluating the selected subject tones of the standard negative should preferably be the same as the printing filters used for the three exposures.

To print an unknown negative:

1. Set up the enlarger, with the unknown negative, to the required magnification etc.

2. With the red filter over the meter probe adjust the enlarger lens aperture until the meter indicates the same exposure time as it did for that subject tone with the standard negative.

3. Without changing the lens aperture again, measure the same area through the green filter probe and read off the green filter exposure required on the meter.

4. Repeat for the blue filter exposure.

5. These three exposures should then yield a correctly balanced print.

With either method of printing fine adjustments are possible on the basis of this first print.

Negatives made on different brands of colour film or printed on different papers each require separate calibration.

Also it is useful to have several standard negatives made on the same type of film, but of subjects under different light conditions: outdoor daylight, clear flash, tungsten light etc. The unknown negative can then be matched against a standard negative of the appropriate type, resulting in smaller and hence more accurate colour corrections.

ELECTRONIC COLOUR ANALYSERS

To speed up work in the darkroom, a number of commercial colour analysers incorporate a series of calibration controls which retain the filtration and exposure data for the standard negative in the instrument itself.

Basically such outfits incorporate a photo multiplier tube built into a probe which is fitted with a filter selector switch. Thus a red, green or blue filter (or no filter) can be placed in front of the cell as required. The amplified photo cell output actuates the needle of the measuring instrument proper. The amplification is however adjustable by means of attenuator circuits which are in turn connected to the filter control on the probe.

When measuring a specific subject tone (flesh tint or grey area) of the standard negative on the enlarger baseboard, each reading through the three filters is adjusted by the attenuator controls so that the meter indicates the filtration and exposure time used for the standard negative.

To make a colour print from an unknown negative it is then only necessary to balance the reading of a corresponding detail in the image through say the red filter to the same value as was set for the standard negative. The readings through the other two filters then directly indicate the required filtration correction for white-light printing or the exposure time through the other two filters with tricolour printing.

Colour analysers may have a number of attenuator banks which can be set to the calibration characteristics of different colour negatives or of different reference areas (subject tones) in one or more negatives.

When printing unknown negatives, it is then only necessary to select the appropriate bank of controls corresponding to the type of negative or subject tone calibrated, and match up the red, green and blue readings to obtain the required data for the new negative to be printed.

INTEGRATION MEASUREMENTS IN COLOUR PRINTING

For black-and-white enlarging integrated readings of the average brightness of the whole negative are, as we have seen (page 275), not too reliable without appreciable correction

for individual negative characteristics. Integrated measurements are much more popular for colour printing for several reasons:

(1) As in black-and-white work, they lend themselves well to automated exposure systems.

(2) Colour negatives tend to vary less in their brightness distribution and contrast, partly because processing is more standardised and partly because the best colour subjects are those of a controlled and fairly uniform brightness range.

(3) In the majority of cases integration provides a rapid and fairly reliable indication of the colour balance of a negative.

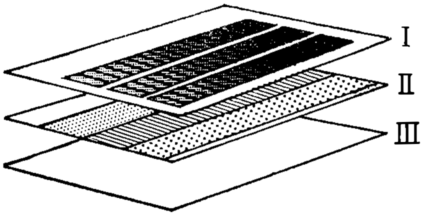
This last point is based on the findings of Pitt and Selwyn as far back as 1938. They showed that when the light coming from an average outdoor scene is thoroughly mixed (for example by completely defocusing its image on a ground glass screen) this mixture is almost neutral (i.e. grey or white) in colour. Moreover, the integrated colour of most subjects does not depart appreciably from this. Assuming that correction filtering to obtain a print of good colour balance has to compensate mainly for the colour of the enlarger light source, the dominant colour characteristic of the negative and the sensitivity characteristics of the paper layers – but not for the inherent subject colours in the negative – we can mix the light coming through the negative and adjust the filtering so that this mixed light would correspond to a neutral grey reproduction.

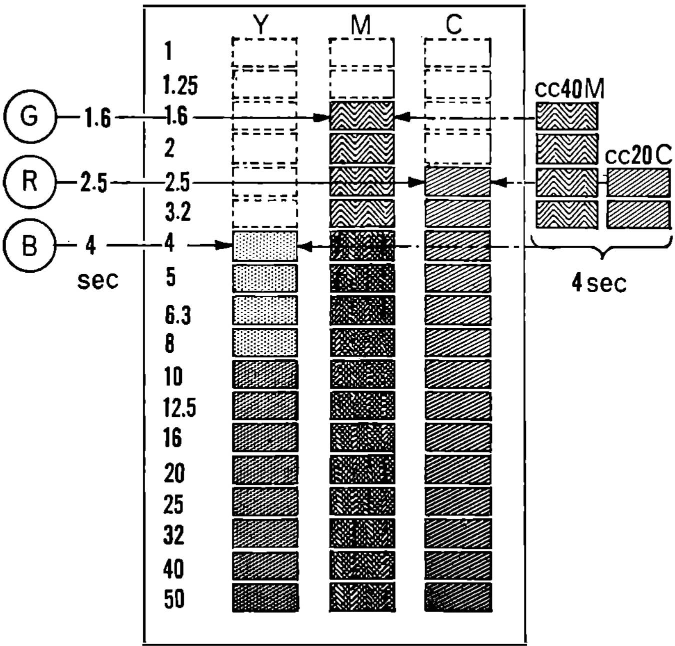
Once a standard negative has been calibrated in this way with a given enlarger and colour paper, all subsequent negatives can be assessed rapidly by such integrating measurements and this can even be done automatically in suitable enlargers (page 302).

The standard negative for this so-called integration to grey is subject to slightly different requirements from those applying to standard negatives for detail or spot readings on the enlarger easel. In the first place the negative should be of a subject with a full range of colours – preferably an outdoor scene in sunlight. This provides the most successful integration to grey.

On the other hand, no new standard negatives are required for different makes of negative film; the integration method automatically allows for different negative charac-

COLOUR EXPOSURE WEDGE





The tri-colour wedge consists of a neutral step wedge I (*top*) laid on top of strips of tri-colour blue, green and red filters (II), the whole placed on top of a piece of the colour paper III and exposed on the enlarger baseboard with the colour negative in the enlarger and a diffuser in front of the lens.

For three exposure printing the exposure times at the left-hand edge of the chart for the first visible step in each colour give the exposure time through the complementary filter (blue, green and red respectively). For white light printing the exposure time is given by the palest step of any colour – here yellow – while the number of steps above this in the two other colours shows the required filter densities of those colours. See also page 301.

teristics provided the subject is still an average one as postulated above. Even the colour of the exposing light is compensated by the grey integration method; the measurement thus corrects for the change in colour rendering of the negative occasioned by the use of flash or artificial light when taking the picture. Integration to grey assumes that the final print should look as if it had been taken by white light and will correct (within certain limits) for deviations from such "whiteness".

Unusual subjects require special compensation. By unusual subjects we here mean scenes containing a large area of predominantly one or two colours instead of the full colour range. The typical and often-quoted example is a shot of a white kitten on a red rug. This integrates substantially to a red, and filter selection based on integration to grey would yield a print of a blue-green kitten on a virtually grey rug. From table XVII (page 290) such a subject would thus require an extra cyan filter density (or less magenta and yellow). Analogous considerations apply to subjects with other unbalanced colour distributions.

THE COLOUR WEDGE METHOD

A simple application of grey integration to colour printing is the tricolour wedge. This consists of a neutral step wedge with density intervals of 0·1 going up to a maximum of about 2·0. This is covered by red, green and blue filter strips running side by side down the length of the wedge. A mask with windows covers the wedge and the filters so that each step prints as a small rectangle or circle against a white background. The steps are usually numbered in exposure times, running from say 1 second for the densest step to 48 or 60 seconds for the lightest. (This numbering has to be related to the conditions of use of the tricolour wedge.)

For an exposure test the negative to be printed is inserted in the enlarger and focused, etc. for the required print size. The enlarger lens is then covered with a diffusing screen and a piece of the colour paper placed underneath the wedge on the enlarger baseboard. This receives a standard exposure, for example 30 seconds.

After processing, the test piece should show the series of yellow, magenta and cyan steps. The series themselves will be of different lengths (page 299). The test is an indication of

the extent to which the light coming through the negative and scrambled by the diffuser, deviates from "whiteness" when recorded by the colour paper. If we assume that the record should be white or neutral, we can correct this deviation by the filtration indicated by the test.

The evaluation of this filtration is fairly simple, both for white light and for colour printing.

(a) *For white-light printing* take the shortest series of steps on the test print. Suppose this is the yellow series, and the first visible step is opposite the indication for 15 seconds. This would then be the basic exposure for a print from that colour negative. If the other two series (magenta and cyan) were of equal length, no further correction would be necessary. If however the magenta series shows say four steps more than the yellow series, too much green light reaches the colour paper to produce a balanced print. This must be removed by additional magenta filtering. Four steps on this wedge correspond to a density of 0·4, hence the magenta correction would be a 40M filter. In the same way if say the cyan series shows two steps above the lightest yellow one, a 20C filter would also be required for the print. Hence the correction is 40M + 20C.

(b) *For three-exposure printing* the exposure times opposite the lightest step in each colour indicate directly the required exposures through the three printing filters (provided these are identical in characteristics with the wedge filters employed). For example a first yellow step of 4 seconds indicates a four-second exposure through the blue filter; four steps higher in the magenta series corresponds to 1·6 seconds – the required green filter exposure. Similarly two steps up in the cyan series would correspond to a red filter exposure of 2·5 seconds. (These exposure values are typical for professional enlargers with a high-intensity light source and accurate exposure timer circuit. The corresponding values for amateur enlargers may be much higher.)

INTEGRATING COLOUR ANALYSERS

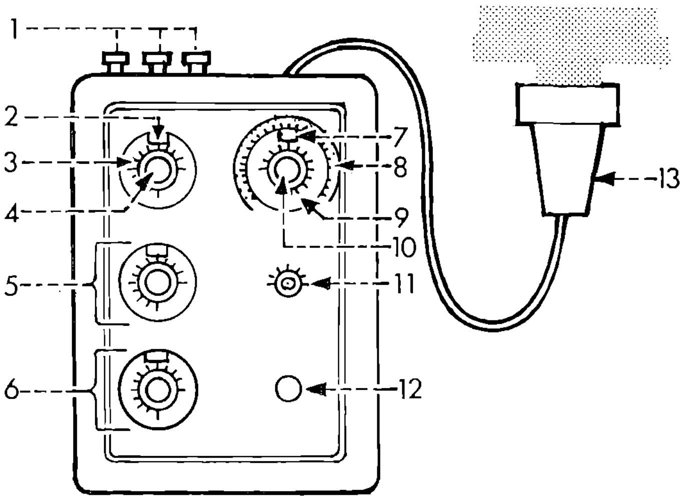
Colour analysers are easily adapted for integrated readings by placing a diffuser in front of the enlarger lens to "scramble" the light reaching the probe cells. This type of instrument is becoming the standard system for advanced amateur and routine professional colour enlarging, as it greatly simplifies and speeds up filter determination and selection both with enlargers using filter drawers and with – also increasingly popular – colour enlarging heads (page 306).

The most convenient form of such an integrating colour analyser uses a three-probe cell (each cell behind its own measuring filter and a diffuser) that fits directly in front of the enlarger lens. Where the connection between the lens and the probe is light-tight, the whole analysis process can take place in ordinary light. Where the probe is used on the baseboard of the enlarger, the operation has to take place in total darkness.

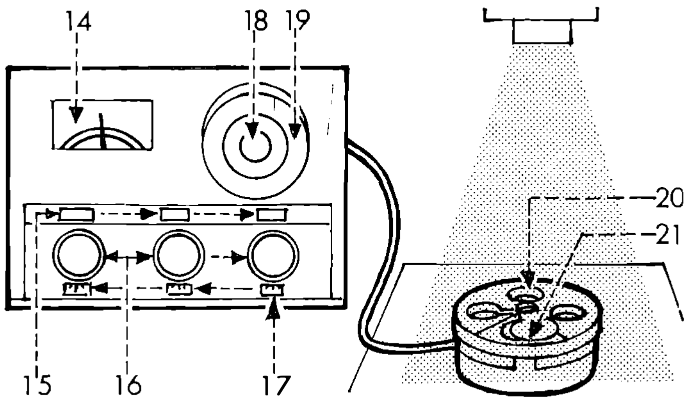
The three cells of the probe are linked to three balancing circuits on the control unit. Adjustment of each balancing circuit then establishes the correct reading for the blue, green and red component of the light reaching the probe. The balance point is usually indicated by signal lamps. The associated control knobs carry scales which at the point of balance indicate the required filter density for a correctly filtered print.

A further balancing circuit connected to all three cells may at the same time indicate the required exposure time and – in advanced instruments – be linked with an automatic timer.

Some analysers of this type have a single photocell in the probe located behind a rotating filter turret (or other arrangement for bringing one of three filters – or no filter at all – in front of the cell) and the readings are then made by successively switching the different filters and also switching the cell output to the different channels of the measuring instrument or control unit. The scales indicating filter densities must be matched to the filter system used (filters of different makes have different numerical values for similar filtering effect) and at least one analyser provides interchangeable filter scales for this purpose on the control knobs.



Typical analyser (Jobomatic) with integrating probe. 1, calibrating controls; 2, signal lamp below interchangeable scale dial 3 of yellow control knob 4; 5, magenta controls similar to yellow; 6, cyan controls similar to yellow; 7, exposure balancing lamp below print size scale 9; 8, exposure time scale; 10, exposure time knob; 11, paper speed control; 12, switch; 13, photocell probe mounted below enlarger lens.



Typical colour analyser (Simtron II) for baseboard readings. 14, meter needle and zeroing scale; 15, channel identifying light; 16, colour control knob (one for each colour); 17, filter scales; 18, paper speed scale; 19, exposure scale; 20, reading filter in turret on probe; 21, swing-away white target for locating probe at selected point of projected image. Integrated readings become possible by fitting a diffuser in front of the enlarger lens.

Calibration again involves making a best possible print from a standard negative on the paper to be used. The negative is then replaced in the enlarger and the same filters inserted or set as were used for the optimum standard print. The light through the enlarger lens is measured with the probe mounted in front of the lens (or on the baseboard with the diffuser in place) and the controls of the colour analyser set to the same filter values. Calibration controls on the analyser can then be adjusted to bring each measuring channel into balance as indicated in the instructions for the unit. Where no separate calibrating controls are provided, the main control knobs are used for balancing and separately movable scales on the knobs set to the filter values used for the optimum print.

For analysing subsequent unknown negatives you then only have to measure the negative in the same way – without filters in the enlarger light path – and adjust the controls of the analyser to their respective balance points. The scales of the controls then indicate the required filters or filter settings. These filters are placed in the enlarger and the reading repeated; this shows up any required fine adjustment. The print may then be exposed with this filter setting and evaluated after processing. With the majority of colour negatives the result should be reasonably correct; any final correction for residual colour casts can be carried out on the basis indicated in table XVII on page 290.

The exposure time is established in the same way via an exposure control on the analyser, using the white-light channel or by adjusting the probe filters so that no filter is in front of the cell. The exposure is also calibrated with reference to the optimum standard print and involves setting the analyser to a paper speed value.

Where the photocell probe is mounted directly on the enlarger lens, the exposure is correct only for a print made at the same magnification as the optimum standard print. Prints at different magnifications require a correction, because the probe measures the same light irrespective of whether the enlarger head is high up or low down on the column. The correction is usually obtained by setting a magnification factor or, better still, by measuring the diagonal of the full projected image. A calculator or other conversion device may be supplied for the purpose.

No such correction is necessary where the analyser probe measures the light intensity on the enlarger baseboard, as the probe there automatically allows for the higher or lower image brightness at each magnification. Alternatively, in the last case, the actual exposure can be obtained by a shadow reading of the negative projected sharply on the baseboard, i.e. without any diffuser in front of the probe cells or cells.

SEPARATE ANALYSIS

Integration to grey can also be carried out as a separate operation before enlarging. There are desk instruments which measure the red, green and blue values of the light coming through the negative and a diffuser when illuminated by a standard light source. These readings can then be related to the exposure and filtration requirements of a standard calibration negative to produce the best possible print. With subsequent unknown negatives the integration readings provide the information for the necessary colour correction.

The advantage of such desk analysers is that the assessment or grading of the negatives takes place completely separately from the enlarging procedure and can usually be carried out in daylight. In professional darkrooms (where such units are primarily employed) such procedures also permit a division of labour. An operator can grade negatives in between other jobs without having to be confined to a darkroom, and the job can be assigned to a specially highly skilled operator (or the photographer himself who wants to control closely the colour effects in the print).

More advanced separate colour analysers may provide various extra features:

(a) Provision for spot as well as integration readings. Here the spot area must be small enough to permit accurate location of the negative portion to be measured, even when using small negative sizes.

(b) Interchangeable "memory" banks. These store the calibration characteristics of different types of colour negatives (e.g. made on different films) or of different colour papers.

(c) Programming attachments to record the required colour settings on perforated paper tape or similar media. Such programmers are however used mainly in commercial photo finishing laboratories to control automated high-speed colour printers (page 318).

Another approach to colour control in printing involves the use of equipment analogous to a colour television circuit. A television camera can, in principle, transmit the image of a colour negative on to a viewing screen in positive colour. Colour control adjustments can then show a visible change in colour balance. If the control circuits of the television system are preset on the one hand to the characteristics of a standard colour negative (calibration negative) and on the other to a desired visual appearance of the finished print, greatly simplified colour grading becomes possible. Here the negative to be printed is inserted in the TV camera system and the colour controls adjusted until the screen shows the required effect. This adjustment of the colour controls from their original setting then provides direct values for the required filtration or exposure modification when the colour negative is printed in a given enlarger.

ADVANCED COLOUR ENLARGERS

The value of rationalising enlarging procedure by rapid colour analysis is largely lost if it is not linked to an equally rational way of adjusting the filtration in the enlarger – without lengthy handling and changing of subtractive filters in a filter drawer. Modern colour enlargers therefore simplify this operation in several ways, leading to two classes of design:

(a) Filter control by dial, where subtractive filters are built into the illumination system. Any filtering effect is obtainable by adjusting two or three controls on the enlarger; and

(b) Automatic exposure control, where the setting of the filtration is monitored either before or during the exposure by means of photo cells built into the enlarger (or else into a special masking frame similar to that described on page 278).

Method (a) is primarily a sophisticated way of operating

a subtractive colour enlarger; method (b) streamlines the whole printing operation as well as the control of the light colour. Semi-automatic and fully automatic systems of this nature can work both with white-light and with tricolour enlargers – often better with the latter since the control elements are simpler.

Advanced colour printing control arrangements may be an integral part of an enlarger or else they may be provided as a conversion kit for black-and-white enlargers. The latter approach is practical since the only difference between a colour enlarger and a black-and-white model is in the light source (i.e. the lamphouse), the colour control provision (which may be built into the lamphouse or be a filter unit near the lens) and possibly a monitoring or colour sampling system of photo cells. If the latter is a unit below the lens or in the masking frame (see also page 317), conversion of a black-and-white enlarger to colour working only involves changing the lamphouse and attaching a colour monitoring or sampling system. A number of leading professional colour enlargers are in fact modifications of corresponding black-and-white enlargers derived by such comparatively simple conversion.

We shall here describe the basic systems; there are numerous variants and elaborations which find use in automatic colour printers in the photofinishing trade (and in the motion picture printing laboratories).

FILTER SELECTION CONTROL

There are two ways of providing continuous colour control in a subtractive enlarger:

(a) By sliding high density cyan, magenta and yellow filters partly into the light path; and

(b) By moving graduated cyan, magenta and yellow filters inside the illumination system.

In both cases the resulting light is non-uniform across the light path immediately after the location of the filters. With the first method where filters obtrude only partly into the light beam, the latter is partly white, partly yellow, partly magenta, partly red (where yellow and magenta overlap) and so on. The light therefore needs thorough mixing before

it reaches the negative; hence such enlargers are diffused light systems – even though they may use condensers between the highly diffused light source and the negative.

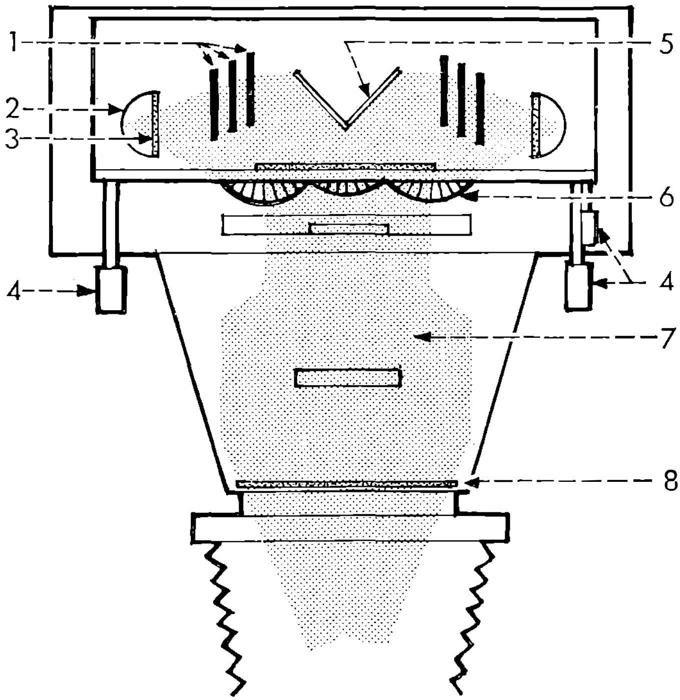
Typically however such a colour head uses an integrating sphere or a reflector system, often combined with fixed or interchangeable mixing boxes (pages 123 and 124). The colour filters move into the light path between the lamp and the integrating sphere or between the light source and the mixing box (page 309). Knobs or other controls adjust the cyan, magenta and yellow filters and show the settings on scales graduated in CC or similar values. The filter density may run up to 1 or 1·5, and the adjustment is continuous; the maximum density can often be increased by inserting auxiliary 1·0 density filters of any of the three colours in a supplementary filter drawer. Fine control of the variable filter then gives precise density settings in the entire range.

For focusing, black-and-white enlarging etc. by white light, the filters are moved fully out of the light path. Some enlargers have an additional control that shifts the whole filter assembly for white light projection, but permits the filters to be brought back again to exactly preselected settings by a simple lever movement.

Since the filters are virtually in the position where the light flood from the lamp is at its most intense, the dyes do bleach in time and the filters have to be changed periodically. This problem becomes more serious still with large-format colour enlargers using colour heads of this kind with lamp powers of 1000 and more watts. Most modern colour enlargers with built-in high-density subtractive filters therefore use interference filters rather than dye ones. Here the filtering effect is due to wavelength-dependent optical phenomena within a number of very thin layers evaporated on to the filter glass rather than to dyes incorporated in it. Such interference filters can be made with absorption characteristics which approximate much more closely to the ideal cyan, magenta and yellow absorptions. At the same time interference filters are completely proof against fading.

Another characteristic of interference filters is a comparative freedom from unwanted transmission; for instance the cyan filter transmits only blue and green with practically no red while a cyan dye filter does transmit also some red. Consequently the interference filters achieve an equivalent

COLOUR MIXING HEAD



This configuration of source and filters is typical of a colour mixing head for a medium format (10 × 12·5 to 13 × 18 cm or 4 × 5 to 5 × 7 inch) enlarger. Smaller models may use only one lamp, still larger ones may have up to four lamps (each with its own set of filters, coupled with all other filters) to provide light power and light spread.

1, set of cyan, magenta and yellow dichroic filters that can be partially moved into the light path of lamp 2; 3, ultraviolet and infrared absorbing filters; 4, controls to move the filters via cams or gears; 5, reflector diverting the light downwards; 6, filter indicating scale; 7, interchangeable mixing box to spread or concentrate the light evenly over the whole negative area 8.

Designs with a condenser system replacing the mixing box 7 are also possible, but would not be significantly more efficient with this type of arrangement.

filtering effect with lower actual densities. As such filters in the colour mixing head are still graduated in density values, these are not necessarily equivalent to the densities of dye filters in the Kodak or Agfa ranges (page 285). In practice a colour mixing head with a filter control range up to a value of 1·3 (generally marked as 130 on the scale) could well be equivalent to 190 or thereabouts on a conventional CC scale. This has to be taken into account when calibrating colour analysers with enlargers of different types.

A continuous control system with graduated filters works in a similar way, but the whole filter moves or rotates to bring denser or less dense sections into the light path. Graduated filters are much more difficult to produce as interference filters than as dye filters. As in view of the advantages explained above, interference filters have largely displaced dye filters in colour heads, the graduated filter arrangement is also disappearing.

In addition to the adjustable filters, colour heads of this type frequently still have a filter drawer either to take additional high-density filters for an extended control range or to hold a mask replacement filter when enlarging unmasked colour negatives. Nearly all present-day colour negative films incorporate dye masks (the orange tint overlaying the image) to improve colour accuracy (page 72) and the sensitivities of the colour print materials are matched to this extra orange tint. When enlarging negatives without such a tint, the colour head would require high permanent yellow and magenta filter settings. It is then more convenient to place a corresponding yellow or orange filter in a filter drawer.

Colour mixing heads of the type described for small-format enlargers utilise a single tungsten-halogen lamp as the light source; larger models may use two or more such lamps.

In principle a light mixing arrangement could even work with three lamps, which offers yet another method of controlling the effective light colour. Here the lamps themselves may be arranged to produce exclusively red, green and blue light respectively. The colour balance is then obtained by adjusting the light strength of each lamp to control the ratio of red to blue to green light reaching the negative.

Tricolour red, green and blue sliding filters of variable

density would not achieve the same result, since such filters in lower densities pass also light of colours they should absorb. Hence a purely filter-controlled light adjustment would in this case have to use neutral density filters in addition to the colour filters.

Although this three lamp illumination – which has been utilised in certain enlargers – uses red, green and blue light like an additive colour printing system, we are still dealing with a single-exposure method. True additive or tricolour printing implies that the paper receives three separate exposures of different duration by red, green and blue light. A simultaneous exposure with all three colours controlled only in their intensity is in principle the same thing as subtractive printing with a filter pack or other cyan/magenta/yellow ratio selection – which filters after all also control the components of red, green and blue light.

MONITORED FILTER SETTINGS

An enlarger with continuous filter colour control can of course be used for colour analysing negatives in conjunction with red, green and blue filtered photo cells in the same way as an enlarger employing filter packs in a filter drawer. That is, we can analyse selected image details for their red, green and blue content and match this analysis to required filter densities with a standard negative, to obtain new filter settings with an unknown negative (page 295).

With colour analysers based on integration measurement (page 297) an enlarger with continuous filter control greatly speeds up grading and measurement of any colour negative by short-circuiting the need for measuring required filter densities and transferring these onto the enlarger. The procedure, once the analyser is calibrated for a standard negative, is to place the unknown negative in the enlarger, set up the measuring probe for integrated readings, and adjust the filter settings in the enlarger until each channel of the analyser is balanced at the calibration settings. In other words, there is no need to adjust the control settings on the analyser, but only the filter settings in the enlarger. As each balance point (yellow, magenta and cyan) is reached, that filter setting is also the correct one for the enlargement.

If the yellow, magenta and cyan channels of the colour

analyser are balanced in this order, it may however be desirable to recheck the balance of the yellow channel after the cyan, as movement of the magenta and cyan filters will have cut down the light reaching the photocell during the yellow measurement. But even with this secondary fine balancing a measuring sequence for an unknown negative need not take longer than half a minute.

In principle it is sufficient to monitor two filter ratios. For we need only consider the filter settings – like the filter packs in a simpler enlarger – as controlling the ratios of red to green to blue light in the mixture. And it is only the ratios which determine the colour balance. Also, with three colours involved, we need to know only the two ratios; the third follows from those automatically. Some simpler colour analysers use a pair of photocells behind a red and a blue filter respectively, connected to a bridge circuit which permits a balancing of the cell output at any desired ratio. The associated control knob then indicates either a yellow or a magenta value. Moving a red and green filter in front of the two cells and switching to another channel on the analyser provides a balance point on a further control indicating magenta and cyan settings.

The point of this arrangement is that enlargers with a similar two-filter adjustment—providing different cyan/yellow and cyan/magenta ratios in the light provides a direct adjustment. Such enlargers used to be available, though they have been displaced by present day colour mixing heads with three movable filters which are simpler to operate.

While the two light ratios are usually balanced in succession by the two filter adjustments, this can also take place simultaneously. In one enlarger of this kind (Simpak) the currents in the balancing circuits measuring the red/blue and red/green light ratio are amplified and energise servo motors to adjust the continuous filtration setting in the enlarger head until all the ratios are balanced. At this point no current flows through the bridge circuits, and the servo motors stop.

AUTOMATIC COLOUR AND EXPOSURE CONTROL

With subtractive printing systems, where the ratios of the red, green and blue components of the exposing light have to

be established separately from the exposure itself, colour balancing of every negative must take place before it is printed. With three-exposure systems it becomes possible to monitor each exposure individually and control its length automatically. The enlarger can then print the negative entirely on its own.

There are various systems – and hence enlargers – using this principle. Most have in common a motor-driven filter changing unit which switches red, green and blue filters successively into the light path. The time during which each filter remains in the light path – and hence the length of each individual tricolour exposure – is controlled by photo multiplier cells. These colour enlargers differ mainly in the arrangement and location of the photo multiplier cells. In fact one cell is generally sufficient, since it monitors the light of one colour at a time. Calibrating controls – usually in the form of potentiometers in the amplifying circuit of the photo multiplier cell – adjust the cell's response during each part exposure to match the sensitivity characteristics of the colour paper used.

Since no mixing of light is involved, such enlargers can have a condenser system for semi-diffused or direct illumination. The filters, generally in a turret, may be placed either in the enlarger head or in front of the lens.

For monitoring, the photo multiplier cell may be incorporated in the base of an automatic masking frame as described on page 278. The cell output then passes to a control unit which contains the balance controls and trips the relay which actuates the filter change. On pressing the exposure button, the complete cycle of the three exposures takes place automatically. The photo multiplier cell in this position allows also for the magnification and hence relative overall brightness of the image on the paper. Special colour printing masking frames may incorporate all the balance controls on the frame itself, and are then used with a motorised filter control unit to be inserted between the light source and the negative in the enlarger.

As in all other systems of semi-automatic and automatic colour balancing, calibration involves making a perfect trial-and-error colour print from a standard negative. The required exposure times through the three filters are then set on the controls of the masking frame or control unit.

For subsequent unknown negatives printed on the same paper, the photo multiplier cell evaluates the difference (during each exposure) between the transmission through that filter of the standard negative and the negative being printed. This evaluation adjusts the three filtered exposures accordingly. For a different paper batch or paper type the instrument has to be recalibrated. Some control units, for instance in the Agfa Colormat system, contain a number of control banks to retain the settings for different standard negatives and/or different colour papers. These control banks are then selected as required.

This system is also adaptable to simpler enlarger designs by incorporating the photo multiplier cell in the lens panel so that it receives the light coming through the negative. The filter unit – consisting of a filter turret and motor to drive it as well as the colour balance and timer controls of the photo multiplier cell – is then located between the light source and the condenser. The colour balance controls have to be preset for each type and batch of the colour paper used. The controls can also provide overriding colour adjustment in the case of anomalous negatives where integration to grey does not yield correct colour prints.

If the photo multiplier cell is situated within the enlarger, a separate control is necessary to adjust the system for different degrees of magnification, since the light reaching the photo cell does not vary much for different magnifications.

SIMULTANEOUS TRICOLOUR EXPOSURES

One way of benefiting from the advantages of tricolour exposures, without the drawback of the increased time involved in successive separate exposures, is to let these exposures take place simultaneously. One obvious way is to have three separate filtered light sources (blue, green and red) which are switched on at the same time and switched off after the appropriate individual exposure times required. If for instance the red filter exposure is the shortest, and the blue filter exposure the longest, the light during the first part of the total exposure would be white (red plus green plus blue); once the red light has gone out, the colour of the light going through the negative would be cyan (green plus blue) and when the green light has gone out it would be blue.

ADDITIVE AUTOMATIC COLOUR ENLARGER

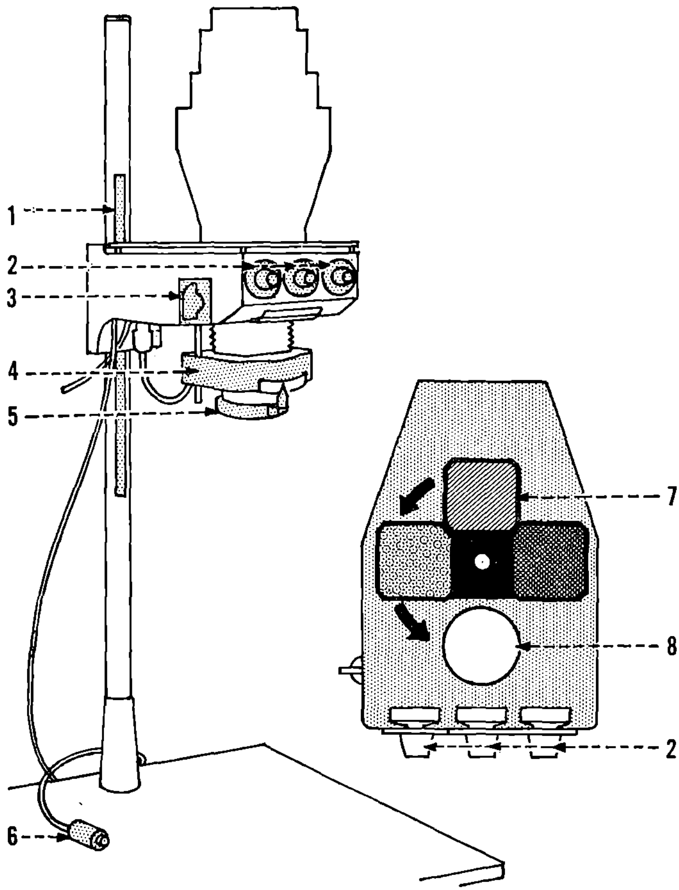


Photo cells on this system – the Colortron 99 enlarger – behind the lens panel monitor the light coming through the negative during each of the successive exposures. When the photo cell output reaches a pre-set level, it cuts off that exposure by moving the filter turret to its next position until the cycle is complete. The insert (*right*) shows the arrangement of the filter turret within the enlarger head. 1, magnification indicator on column; 2, colour control knobs; 3, magnification correction; 4, lens panel with built-in photo cell; 5, aperture adjustment; 6, exposure button; 7, filter turret; 8, condenser (the filters are between the light source and the condenser).

Such an arrangement is used in some high-speed automatic printers.

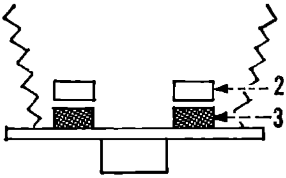
The same result can be achieved with a single light source and three high-density complementary filters – cyan, magenta and yellow. In this case the white light goes on at the beginning of the simultaneous exposure times. At the end of the red-filter exposure, the cyan filter drops into the light path. After the green-filter exposure is ended, the magenta filter cuts in; the combined effect of the cyan and magenta filters is to pass through only blue light. At the end of the blue-filter exposure the yellow filter comes into action. If this is the last of the filters, the light goes out at the same time. With this scheme the three subtractive filters can of course cut in in any order, depending on the relative length of the three part exposures. That is why all three filters are necessary, though in the above example the yellow filter has no controlling function since the blue light exposure is the longest.

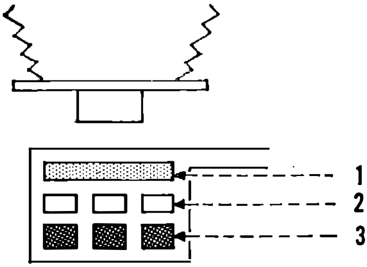
The filters involved can be high-density dye filters, though most enlargers using this system nowadays employ interference filters (page 308). The movement of the filters themselves is controlled by solenoids which are actuated by the same type of circuit as required for automatic additive exposures – with the same provisions for integrated exposure control and colour control. In such a fully automatic system the monitoring photo-multiplier cells (three are required to measure through red, green and blue filters) are either mounted in an automatic masking frame (page 278 and 314) or may receive part of the light through a beam splitter mounted below the enlarger lens (page 317).

As an alternative to being built into an enlarger, a simultaneous additive exposure system can consist of the three subtractive filters mounted in a control unit below the enlarger lens. This can then be fitted to almost any normal enlarger. It has to be used in conjunction with an automatic masking frame containing the monitoring photo cells, plug a control unit on which the timing of the filter-controlling solenoids can be matched to the response of the photo cells and/or to special colour balance adjustments.

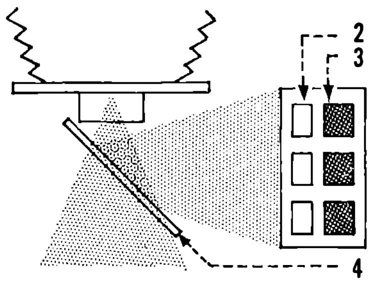
HIGH-SPEED AUTOMATION

The automated colour enlargers described above are mostly beyond the means of the amateur photographer. They

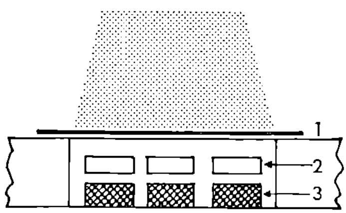




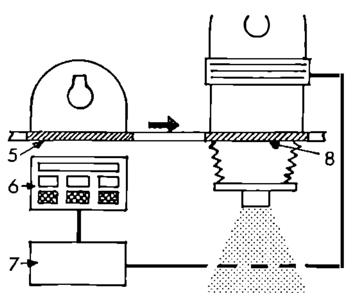
Three photo cells (3) behind red, green and blue filters (2) situated behind the lens panel (*top left*) effectively "see" diffused light from the negative. For additive (three-exposure) printing with successive exposures a single cell is sufficient and can automatically control each exposure in turn.



Some subtractive enlargers use a photo cell unit which swings in front of the enlarger lens for the measurement (*top right*). The unit consists of a diffuser (1) and the three photo cells (3) behind their filters (2). Alternatively, the photo cells and their filters may receive the light via a beam splitter or mirror (4) positioned or swung underneath the enlarger lens (*upper centre right*).



In automatic colour masking frames (*lower right*) the photo cells (3) behind their filters (2) are located underneath the colour paper (1) which also diffuses the light reaching the cells. This arrangement is similar to that of the automatic masking frame on page 277.



On high-speed commercial colour printers working with continuous strips of negatives, one negative (5) may be measured while the previous negative (8) is being exposed. Here a photo cell and filter assembly (6), similar to that shown *top right*, records the colour balance of the negative (5) and stores the result in a control unit (7) until the negative advances into position (8) for printing.

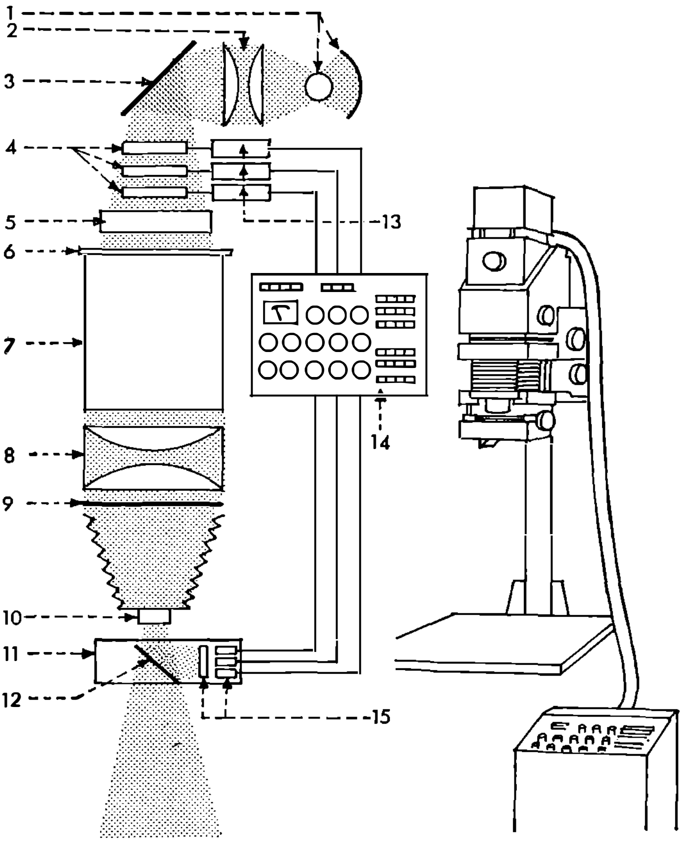
have two justifications for the professional: (1) They speed up operations sufficiently to allow the professional darkroom to cope with an appreciable work load; and (2) they allow darkroom staff to be trained to make good colour prints more or less automatically, or at least without an expert understanding of the theories of colour photography.

This situation becomes still more pressing in commercial photo finishing laboratories where outputs of many thousands of prints per day are involved. Automation of the colour enlarging equipment there goes several steps further. High working speeds become possible by handling the negatives and the paper in continuous strip and roll form and by making enlargements of standard magnification. High-speed commercial printers mostly work by additive (successive or simultaneous) tricolour exposure systems with high-intensity light sources which reduce the total exposure time to somewhere around one second per print. Purely subtractive methods requiring filter density adjustments are practically never used in commercial mass printers – they are too slow. Exposure measurements are based on integration to grey with photo cells sampling the light via a beam splitter in the optical path. The printer has to be calibrated to each make and batch of colour paper used. Usually several such calibration settings can be retained on multiple banks of calibration controls, so that changing from one paper to another involves only switching to a different bank of control settings. The operator may still have to make individual colour and density corrections for negatives deviating from a standard density or subject colour distribution.

Some finishing laboratories employ a skilled colour grader who examines and marks negatives beforehand according to the exposure and colour corrections required in printing. In this system the corrections required are marked by punching notches or holes into the film edge in a coding machine. The actual printing can then be done by less skilled operator who sets the balance controls of the printer according to the grading code on each negative.

This corresponds to separate grading with colour analysers as indicated on page 305. Instead of code notching the edge of the film, some automatic pregraders employ perforated paper tape (similar to programming tapes) on which the

THE DURST CCU 100 SYSTEM



This unit, designed for use with most of the professional Durst enlargers, works on the simultaneous additive exposure principle. It uses a colour sampling unit with beam splitter (in principle similar to that of page 317, *upper centre*) which contains photo-multiplier cells. These are linked to a control unit and determine the instants at which solenoids swing subtractive interference filters into the light path to terminate the appropriate tricolour exposures. 1, lamp and reflector; 2, condenser of lamphouse unit; 3, mirror; 4, subtractive high-density filters (controlled by solenoids 13); 5, filter drawer for additional correction filters; 6, ground glass screen; 7, light mixing box; 8, condensers (used with some enlargers); 9, negative; 10, enlarger lens; 11, light sampling unit; 12, semi-reflector; 14, control unit with three calibration channels, colour correcting keys, density correcting keys etc.; 15, photo-multiplier cells with filters and a diffuser.

grading information for each negative on a roll is punched. The paper tape is then fed into the printer together with the negatives, to control automatically the colour adjustments for each print.

With printers of such high outputs (which may reach 2000 to 3000 prints per hour) it is impossible to aim at an absolutely correct print for every exposure. There is therefore a certain rejection rate of unacceptable prints; these are identified during a final check of the processed roll of prints and the appropriate negatives reprinted.

PRINTING COLOUR TRANSPARENCIES

A colour transparency, usually produced in the camera on a reversal colour film, is a positive picture. To obtain positive prints from it, we can either:

(a) Make an intermediate colour negative on a special negative film and print this in the same way as a normal colour negative; or

(b) Print the transparency directly on to a reversal colour paper. We are here concerned with the second method.

When making prints from transparencies we have to compress the density range of the transparency into the much more limited tone range of a paper (see also page 86). The problems arising from this affect not only tone reproduction but also colour rendering. In those fields of commercial practice where colour transparencies serve as originals for reflection prints, the solution of these problems involves complex procedures, including masking processes.

For straightforward photographic printing on reversal paper we can avoid some of the difficulties by a studious selection of the transparencies to be printed. Thus such transparencies should have a comparatively low contrast and preferably saturated colours. The ideal transparency for printing is a slightly under-exposed one without excessively thin highlight areas.

Even so, a print from a transparency is generally inferior to the original transparency in faithfulness of colour reproduction. This is in part because the dyes used in a colour image do not behave exactly the way they should for theo-

retically optimum colour reproduction. In colour negatives some of these shortcomings are often compensated by so-called integral masking images; it is these which give certain negative films their apparent overall orange or yellow tint.

In a colour negative, which is only an intermediate stage to a colour picture, such tints do not matter; in a colour transparency which is an end in itself, no colour correction of this kind is possible. (In commercial printing practice masking methods again take care of that.) When printing colour transparencies on to reversal paper we therefore have to put up with a certain degree of unavoidable colour distortion. This cannot be corrected by filtration during printing, because the various colours in the picture are affected in different ways and to different degrees.

The printing procedure with colour transparencies largely follows the same principles as enlarging colour negatives. Only the processing is notably different – and usually longer unless a dye-bleach process is used (page 383). Certain aspects of exposure and colour control have however precisely the opposite effect from that in printing colour negatives on a positive paper.

(1) A reversal image is darker, the less the exposure it has received, and lighter the longer the exposure. This is because reversal processing is in effect a combination of negative development, positive printing and positive development (page 442). So if a reversal print is too dark, we must increase the exposure for the next print; if it is too light, we must decrease the exposure.

(2) For reversal printing from transparencies we can use the same colour control methods as for negative-positive printing – i.e. either white light printing with subtractive filter control or successive additive printing with tricolour filters. However, in white-light or subtractive printing, an excess or cast of a given colour in the print is corrected by increasing the density of that filter colour in the filter pack. So if a print is too yellow, it needs less yellow in the filtration (or more cyan plus magenta density).

With tricolour printing an excess of a colour is similarly corrected by reducing the exposure through the filter of the same colour (or the filters which between them produce that colour). Hence too much red would need less exposure through the red filter, or more through the blue and green.

In Tables XVI and XVII (pages 288 and 290) the required corrections for reversal colour printing are obtained by transposing the headings to the second and the third columns. These recommendations are summed up briefly in Table XVIII below.

XVIII – PRINTING CORRECTIONS FOR COLOUR TRANSPARENCIES

If Print Shows Too Much	*White-light Printing: To Adjust Filter Density*		*Tricolour Printing: To adjust Filter Exposures*	
	Add *OR*	*Subtract*	*Increase* *OR*	*Reduce*
Magenta	Yellow + cyan	Magenta	Green	Red + blue
Red	Cyan	Yellow + magenta	Blue + green	Red
Yellow	Cyan + magenta	Yellow	Blue	Red + green
Green	Magenta	Yellow + cyan	Red + blue	Green
Cyan	Magenta + yellow	Cyan	Red	Blue + green
Blue	Yellow	Magenta + cyan	Red + green	Blue

Developing Black-and-White Prints

During exposure an enlarging paper undergoes the same change as a film in the camera. In both cases the invisible or latent image caused by the action of light must be developed or rendered visible by the action of a developer.

DEVELOPMENT METHODS

Black-and-white prints are usually processed either:

(a) In a dish, by passing the print through the successive solutions of the processing sequence in separate open dishes; or

(b) In a roller processing machine.

In contrast to films and to colour papers (page 370) tank development is rarely used for single-sheet black-and-white prints. This is mainly because loading individual papers into a processing basket for tank development (page 371) generally takes longer than the whole development stage of the print in a dish. As a result it is practical to examine prints one by one as they are processed – for instance with a view to exposure correction if an enlargement needs reprinting.

Print processing machines, other than roller processors as described on page 232, exist for taking single sheets through the full processing sequence of development, fixing etc. They are however complex and expensive – and rarely a worthwhile investment except in very big processing departments. Where the printing output is such that continuous rolls of paper are used, these may be developed either in suitable tanks or even in more elaborate continuous processing machines.

MANIPULATION FOR DISH DEVELOPMENT

When placing the print in the developing dish, the developer should flow quickly and evenly over the whole surface. So tilt the dish slightly, so that the developing solution accumulates at the lower end. Then place the paper in the dish and

quickly lower the raised end so that a wave of developer flows smoothly over the whole surface of the print. Look out for any possible air bubbles, and dislodge them if necessary by a touch with the developing forceps.

Normally prints should be inserted in the developer with the sensitive surface upwards. With thin papers it is sometimes convenient to start with the emulsion side down, and after the first wetting of the print draw the latter through the developer, then reverse it so that the sensitive side is uppermost. This usually ensures even and quick wetting of the whole print.

Keep the dish in gentle movement by rocking during the whole time of development, thus ensuring even action of the developer.

This method of dish development permits observation of the beginning and the progress of the development process. When the print has reached its full density, lift it out of the dish with the forceps, let it drain for a couple of seconds, and drop it in the stop bath. Be careful not to immerse the developing forceps themselves in the stop bath; instead take over from this point with the fixer forceps. The stop bath is followed by the fixing bath and the final processing stages (washing – page 350, and drying – page 358).

We need thus a minimum of three dishes for the developer, stop bath and fixer (or four dishes when using two fixing baths – page 347). The dishes should be set up well away from the place where unexposed paper is stored or handled; that is why the darkroom is best arranged with well separated dry and wet benches (page 213). The dishes themselves should also be so placed that the developer cannot splash into the fixing bath, or – more important still – neither the fixing bath nor stop bath can splash into the developer.

DEVELOPMENT TIME AND TEMPERATURE

The development of a print, unlike that of a negative, has to go virtually to completion to produce pictures of good full shadow tones. The recommendations of most manufacturers, usually stipulating development for $1\frac{1}{2}$–2 minutes at 68°F (20°C), should therefore be regarded as minimum times. In practice it is indeed safer to carry on development for at least 3 minutes with normal bromide papers; that way we can be sure that the image is fully developed.

Once the paper is immersed in the developer, very little happens for the first half minute or so. Then the image gradually begins to appear and rapidly gains depth until it seems to change no further. Removal of the print before the image is fully developed out – even if the enlargement was over-exposed – is not recommended; it yields brownish or even greenish blacks. The only remedy is to make a fresh print with a shorter exposure time.

There are two exceptions to this rule:

(1) Certain chlorobromide papers have a rather greater exposure and processing latitude. There an over-exposed print removed prematurely from the developer still shows good tone values. The print contrast in this case is however reduced – just as slightly longer development gives increased brilliance.

When working along these lines it is worth remembering that a wet print in the dish usually looks both darker and more contrasty by the darkroom illumination, especially if this is an orange safelight. Yellow-green safelights give a more faithful indication of the image appearance. However it is best to judge the print quality by white light – once the paper is in the fixer.

(2) With warm-tone papers and developers (page 335) the image tone depends on the development time, as well as on the exposure and the composition of the developer.

Over-development beyond about 3 or 4 minutes is rarely recommended, since the image gains little or no density after this time. Prolonged development is however liable to produce fog and staining. So if the picture is too light after 3 minutes of development, again make a fresh print.

The above notes assume a normal processing temperature, i.e. not below 60°F (15°C) and not much above 70°F (21°C). Within this range the exact temperature is not very important, especially if the print receives at least 3 minutes developing time. At higher temperatures the time should be reduced – again to prevent staining; lower temperatures are not advisable, since some of the developing agents in a developer may completely lose their activity if the solution is too cold. This changes the developer characteristics, even with increased development time. In cold weather some form of dish warming (page 230) is therefore advisable.

More accurate time and temperature control is desirable

when processing prints in a tank or by machine. Precision control of processing is indispensable when handling colour papers (page 361).

ACCELERATED PROCESSING WITH PLASTIC-COATED PAPERS

Many modern enlarging papers are plastic or resin coated (type RC or PE papers). They carry a polyethylene or other plastic layer laminated to each side of the paper base. This prevents the base from absorbing the processing solutions. It also speeds up some of the processing stages, especially washing and drying, because residual chemicals and water have to be removed from the emulsion only. They cannot permeate the paper. The total handling time of a print from dry to dry can in this way be reduced to around 4–5 minutes instead of the traditional three-quarters of an hour. In fact, short immersion times are desirable for plastic coated paper as long immersion does cause some liquid to seep into the paper base along the edges and may eventually lead to frilling through local delamination of the plastic coating. The trend is therefore to speed up the processing sequence further by using more active developers and high speed fixers. As ordinary enlarging papers without plastic coating are still on the market, the following sections compare the handling of both types.

This accelerated processing applies to normal temperatures, i.e. about 20°C or 68°F. Increasing the processing temperature can speed up matters still more. This is equally feasible for the chemical handling stages (developing, fixing etc.) of non-coated papers but does not offer any practical gain as the processing sequence is still dominated by the lengthy washing step. But with washing cut to a minute or two it becomes feasible to use roller processors combined with high temperature treatment (with the solutions kept at 35–40°C or 95–105°F) with suitable temperature control built into the machine. Such roller processing is not only more convenient than passing prints through a set of dishes but also appreciably increases the output capacity of a professional darkroom. Papers processed with a fixing and washing sequence (i.e. not by stabilisation) do not suffer from the limited long term stability of stabilisation materials. They are therefore replacing stabilisation papers

from the professional scene except where the still greater processing speed (10 to 15 seconds) of stabilisation papers is essential and long-time keeping less important.

Plastic or resin coated papers originated in the colour field where the absorption of various mutually incompatible chemicals by an unprotected paper base was liable to cause problems in the more critical processing sequence of colour prints.

MANIPULATION WITH ROLLER PROCESSORS

A roller processing machine (page 232) is necessary for rapid processing papers incorporating the developing agent in their emulsion (page 78). The processing time here is fixed by the speed with which the rollers pull the paper through the machine. It is therefore important to keep the solution temperatures at a level where their ingredients are sufficiently active to complete the job they have to do.

In cold weather the activator and stabiliser solutions should be pre-warmed to the right temperature (indeed a little above) before being filled into the processer trays or reservoirs. (Usually the solutions are supplied in plastic bottles; it is an easy matter to stand these in a dish of warm water for 5–10 minutes, as required.)

With high-temperature roller processors for plastic coated papers all solutions must be brought to the working temperature beforehand. Such machines generally have provision for temperature control, possibly with heaters and thermostats in the more sophisticated versions.

To develop the print in a roller processor, simply feed the edge of the print through the entrance slot at the front of the machine. Make sure that the rollers evenly grip the paper edge and pull it in. Feed the paper in straight, especially in the larger sizes. If the paper goes in askew, it may foul the sides of the loading slit by the time the trailing edge has reached the slit, and so fail to pass through the rollers at all. Usually this results in the paper being chewed up in the machine; you then generally have to stop the machine, possibly lift out the rollers and remove the paper before carrying on.

When feeding in the paper make sure also that it does not crease; this leads to undeveloped streaks across the image.

Thin-based papers should be fed in along the direction of

their paper grain, i.e. with their direction of curl at right angles to the travel direction through the machine. This reduces the risk of the paper wrapping itself round the final squeegee rollers. Usually stabilisation papers are cut and packed with their curl in the direction of the short side of the paper format. So it should be the short side of the print which is fed into the rollers. If however larger sheets are cut down, the curl may well be across the long side of the reduced format, and the paper should be fed in accordingly – subject to the minimum paper size the machine can handle (below).

With roller processors there is a limit to the smallest paper format that can be fed in. This is set by the longest path length between any successive sets of rollers handling and transporting the paper. In a stabilisation processor it is usually the distance between the developing rollers and the final squeegee rollers; in processors running PE-type papers through a developer, mixer and washing step the longest path length may be rather more. Each set of transport rollers or squeegee rollers has to grip the paper before it has left the previous set of rollers, otherwise the print simply remains in one of the baths and does not come out of the machine.

With small machines the minimum pass-on length may be as little as 10 to 12 cm (4 to 5 inches); this can thus take a print as small as 6 × 9 cm fed in diagonally. With larger machines, especially roller processors for PE papers, the path length may be twice as long which implies a minimum print format of around 13 × 18 cm or 5 × 7 inches even with diagonal feeding.

When the print emerges from the final squeegee rollers after stabilisation or after fixing and washing it needs no further treatment (but see page 348 for stabilisation processed prints). Such damp prints dry on their own in 5 to 10 minutes, or can be dried faster still in a suitable drier (page 358).

Two further points are particularly important with stabilisation processes, but also apply to the other type:

When working with a roller processing unit check that the solutions in both trays are up to the recommended levels. The activator especially is carried over into the stabilising bath, so that the activator tray needs periodic topping up.

On some machines this can be done automatically.

When filling up the trays be careful not to spill any solutions; especially avoid contaminating the activator with stabiliser. This not only greatly reduces the working life of the activator, but also produces a strong smell of ammonia which is liberated by the reaction between the highly alkaline activator and the ammonium salts in the stabiliser. To avoid spillage and contamination never move – or even knock against – the processing machine when it is filled up with solutions.

THE COMPONENTS OF A DEVELOPER

The development of printing papers is a more or less mechanical matter. Successful results depend primarily on the following two factors:

(1) Adequate development time for the type and make of paper in use – see above.

(2) The correct choice of a developer formula. To deal intelligently with this point is necessary to have some understanding of the action of the various components of a developer. The following notes relate less to the chemical aspects of the subject – which is hardly of interest to the practical photographer – but to the manner in which the composition of the solution can affect the image colour, gradation, maximum black and freedom from faults in a paper print.

Developing Agents. The commonest developing agents, especially for papers, are metol, phenidone and hydroquinone. The proportion in which they are present however varies greatly in different formulae and this affects the image characteristics of the print.

The usual metol/hydroquinone ratio for bromide paper developers ranges between 1:4 and 1:8. The higher hydroquinone ratio tends to give more contrasty prints, while a developer with metol only (page 337) gives soft results.

Phenidone has, like metol, the ability to activate hydroquinone in mixtures of the two. (The activity of either type of combined developer is much higher than of developers with one of the agents only). The amount of phenidone required for the purpose is however much less than of metol and the usual phenidone/hydroquinone ratio is around 1:25. One of the advantages of phenidone is that it is one

of the least toxic developing agents known. It is very unlikely to cause dermatitis with normal users.

With hydroquinone alone exceedingly contrasty developers can be made up, though in this case normal alkalies must be replaced by caustic soda or potash.

Other developing agents in fairly common use for negative processing are rarely used for papers, mainly because there is simply no point in employing them. Thus the need never arises for low-energy fine grain or high-acutance formulations, while other developing agents may give unsatisfactory print tones, produce stains or require excessively long development times.

Preservatives. Sodium sulphite is normally used as a preservative for the developing agent, and this chemical has already been discussed in connection with fine grain developers (page 60). In development papers the ability of sodium sulphite to dissolve silver bromide in an emulsion tends to make the image colour warmer.

Alkalies. The most commonly used alkalies for print development are sodium and potassium carbonates, and the caustic alkalies – sodium hydroxide (caustic soda) and potassium hydroxide (caustic potash). These substances provide the necessary developing energy for practical use, since developing agents alone are at best very weak and slow in their action.

Increased alkalinity makes the developer produce purer black tones in the print and also increases contrast. Hence any energetic developer with caustic alkali will give a more contrasty image on the same paper with the same negative than one containing an alkaline carbonate.

Equally, caustic alkalies increase the speed of action of the developer. For this reason they are used as the basis of activator solutions for roller processors (page 340).

Restrainers. The main chemical used for this purpose is potassium bromide and it reduces the risk of veil or fog appearing in the print. Developers must still be free from fogging tendencies when used at higher temperatures or with prolonged development times.

Since excess potassium bromide also tends to give an unpleasant greenish black image colour, the amount to be included must be kept to a minimum. With suitable formulations however the effect of potassium bromide on develop-

ment time and image colour can be utilised for warm-tone development with suitable papers (usually of the slower chlorobromide variety).

Certain organic compounds such as benztriazole and nitrobenzimidazol are also used as restrainers. Their action is rather different from that of potassium bromide, in that they do not slow down the development rate so much. These organic restrainers or anti-foggants, sold under proprietary names as developer improvers, produce particularly rich black or blue-black tones and are especially effective in keeping down fog in stale papers.

The improvement in image tone is also obtained with reduced development times which would otherwise lead to poor blacks. This in effect increases the latitude of a paper, as wrong exposures can be compensated to some extent by shorter or longer development time without seriously interfering with the quality of the picture.

Such developer improvers are used in very small quantities, 1 part in 10,000 of the developer being a satisfactory proportion. Commercial developer improvers are usually sold as 1 per cent solutions.

Other Developer Additives. Commercially packed developers may include other undisclosed additions to improve keeping qualities, working life etc. One such additive restricts the formation of precipitates when developers are dissolved in tap water. Most commonly the precipitate is the carbonate of calcium or magnesium, formed by interaction between the alkali carbonates in the developer and the dissolved calcium and magnesium salts in the tap water. It is these salts which are responsible for the "hardness" of the water. If the water is not very hard, such a precipitate is merely a faint opalescence or clouding, and has no effect on the activity of the solution.

Wetting Agents. Most packed developers nowadays include a wetting agent. Its function is to assure rapid and uniform wetting of the whole paper surface when a dry print is first immersed in a processing solution. This therefore helps developers etc. to act more uniformly during the first moments of immersion, and lessens the risk of air bubbles clinging to the print surface. The wetting agent acts by reducing the surface tension of the liquid (i.e. the water of the solution).

Wetting agents are widely used in many branches of industry; photographic wetting agents are available in solution form and may be added to developers that do not already contain them. The recommended proportion is usually about 2–4 c.cm. per litre of working developer. (No wetting agent is needed in stop baths, fixers etc., as the print is already wet. When handling films, a wetting agent in the final wash helps the film drain more fully and dry more evenly afterwards.)

A few drops of wetting agent may also be added to toners and other aftertreatment baths in which prints are immersed dry. Added to spotting or retouching colours and to other solutions for local treatment on the finished print, the wetting agent aids accurate coverage of specific print areas.

Anhydrous and Crystalline Salts. In the formulae given in this book anhydrous salts are usually specified. To convert the quantities to crystalline salts, the following factors must be used:

Sodium sulphite: double the weight given for anhydrous salt if crystalline salt is used.

Sodium carbonate: multiply the weight given for anhydrous salt by 2·7 if crystals are used, or by 1·17 if the monohydrate is employed (this is the normal form in the U.S.A.).

Sodium and potassium carbonates give virtually identical results in a photographic formula if 1·3 parts by weight of potassium carbonate are used instead of 1 part of anhydrous sodium carbonate. Conversely, one part of potassium carbonate can be replaced by 0·77 parts of anhydrous sodium carbonate or 0·9 parts of sodium carbonate monohydrate.

MAKING UP SOLUTIONS

The formulae on pages 334–338 are given partly to provide a comparison between leading popular formulae in the light of the above notes. Partly they of course provide the photographer who wants to make up his own formulae with the necessary recipes.

The general procedure for making up a formula is not difficult, though somewhat cumbersome. The ingredients are first weighed out one by one on a reasonably accurate balance. This should be precise within 0·02 gram. Generally quantities weighed out should be accurate within about 5 per cent of the indicated amount. The chemicals are then dis-

solved in warm water, using about three-quarters of the final volume.

Dissolve the developing agents first, followed by the sulphite, alkali and other ingredients. Always stir thoroughly until each ingredient is dissolved before adding the next one. Finally make up to the indicated volume with cold water, filter into a stock bottle and let the solution cool to the normal processing temperature (about 16–21°C or 60–70°F) before use.

Ingredients required in very small quantities – mainly potassium bromide and developer improvers – are best made up separately as a 10 per cent or 1 per cent solution respectively to facilitate the addition of an accurately measured amount to the developer.

Making up processing solutions from individual chemicals can afford a certain economy in a large printing laboratory, but it is rarely worth-while either in a medium-size professional darkroom or for the amateur. On the one hand the individual chemicals have to be bought and stocked in not necessarily economical quantities; on the other the operations of weighing out and dissolving must be carried out meticulously and cleanly. They also require appropriate space for the purpose *outside* the normal darkroom; spilt chemicals and chemical dust are always a source of spots on prints and other troubles.

Despite their higher price, ready-packed developers and other processing formulae – if possible in liquid form – are therefore a far better proposition. These need only to be diluted with water; this not only saves time but also makes it unnecessary to invest in accurate weighing facilities. Home compounded formulae are indeed advisable only for special processes where no ready-made solutions are available commercially.

Prepared liquid developers have three further advantages:

(1) They are made up to a high standard of accuracy and so ensure more consistent results.

(2) They are often available in more concentrated form than the stock strength stipulated by published recipes.

(3) Undisclosed additives often ensure better keeping qualities than with published formulae. It can even be argued that the home compounding of processing solutions is as

out-of-date in modern darkroom practice as coating one's own printing papers!

With this proviso we shall compare a number of the more popular formulae in current use.

UNIVERSAL DEVELOPERS

These formulae are suitable for all kinds of contact or enlarging papers (see Table XIX). They differ however somewhat in the image colour – which of course depends also on the type of paper used.

XIX – UNIVERSAL DEVELOPERS

Ingredient	**12** *Univ. M.Q.*	**13** *D163*	**14** *Univ. P.Q. ID62*	**15** *Blue-black*	**16** *New Winchester*
Metol	2	2·2	—	2	3·5
Phenidone	—	—	0·5	—	—
Hydroquinone	3	17	12	6	8·6
Sodium sulphite, anh.	25	75	50	25	35
Sodium carbonate anh.	25	65	60	35	63
Potassium bromide*	1	2·8	2	0·5	1·9
Anti-foggant** solution	—	15–25	20	10	37
Wetting agent sol.	—	—	—	—	10
Water to	1000	1000	1000	1000	1000
Working dilution	Full strength	1:3	1:3†	Full strength	1:2

All quantities in grams or (liquids) ml.

* Best added as a 10 per cent solution, using 10 times the indicated quantity.

** Commercial developer improver solution, or 1 per cent benztriazol or nitrobenzimidazol.

† Dilute 1:1 for chloride contact papers.

Formula No. 12 in Table XIX (above) gives pure black image tones on normal bromide papers (group *c* on page 80). It gives warm black tones on chlorobromide contact and enlarging papers – groups *b* and *d* – and pure black to blue-black image colour on chloride contact papers of group *a*. The developer is used at full strength for all these paper types.

Formula No. 13 is similar in characteristics and is an

established universal paper developer by Kodak. No. 14 has similar characteristics but employs phenidone in combination with hydroquinone.

No. 15 is a special blue-black formulation of increased energy with a higher alkali content but lower potassium bromide than No. 12. It gives blue-black image colours on normal bromide papers (group *c* on page 80) and pure black tones on chlorobromide enlarging papers of group *d*. The addition of anti-foggant is optional, but shifts the image colour further towards blue-black. (The anti-foggant is specified as an optional additive also for formula No. 13.)

Formula No. 16 is the "new Winchester" formulation published many years ago as a universal paper developer for rich black tones with good keeping qualities and low staining tendency. It is still a favourite and includes not only anti-foggant but also wetting agent. This is also available for photographic purposes under various proprietary descriptions. Wetting agents are incidentally also included in ready-packed developers sold by most manufacturers. The wetting agent can equally be added to any of the other formulae in Table XIX to ensure more uniform wetting of the paper surface when the print is pushed into the developing dish.

WARM TONE DEVELOPERS

As already noted, the image colour becomes warmer as the amount of potassium bromide and sulphite in the developer are increased. The warm black developer below is formulated along these lines and is intended mainly for rapid chlorobromide papers (group *d* on page 80) but suitable also for papers of group *b*.

17 – WARM BLACK TONE DEVELOPER

Metol	35 grains	2 grams
Hydroquinone	110 grains	6 grams
Sodium sulphite, anh.	$1\frac{3}{5}$ ounces	40 grams
Sodium carbonate, anh.	$1\frac{2}{5}$ ounces	35 grams
Potassium bromide	35 grains	2 grams
Water to	40 ounces	1000 ml

For really warm brown tones there are a number of developers based on hydroquinone with or without other

developing agents (but not metol). The tones obtainable depend very much on the actual chemical constitution of the emulsion used with the developer, and for this reason the makers of warm tone papers usually give detailed recommendations for the best developer formulation and the way it is to be used. For the sake of completeness details of one developer of this type are given below.

18 – BROWN-TONE DEVELOPER

Hydroquinone	1 ounce	25 grams
Sodium sulphite, anh.	$2\frac{2}{5}$ ounces	60 grams
Sodium carbonate, anh.	$3\frac{3}{5}$ ounces	90 grams
Potassium bromide	18 grains	1 gram
Water to	40 ounces	1000 ml

This solution is normally diluted with three volumes of water and the time of development – with warm tone papers – is between 2 and 3 minutes for a cold brown tone. For warmer tones the exposure is increased and the developer diluted; frequently additional potassium bromide is added (but not anti-foggants – which cause the tone to go to cold black again) in order to keep the actual bromide concentration in the working solution constant. This procedure frequently leads to very long exposures, extensive development times and very soft image gradation.

For tones of a colder brown, approaching sepia, the following formula is useful:

19 – SEPIA-TONE DEVELOPER

Hydroquinone	140 grains	8 grams
Glycin	1 ounce	25 grams
Sodium sulphite, anh.	$2\frac{2}{5}$ ounces	60 grams
Sodium carbonate, anh.	$3\frac{3}{5}$ ounces	90 grams
Potassium bromide	35 grains	2 grams
Water to	40 ounces	1000 ml

The glycin in this formula will only dissolve completely after the alkali has been added to the solution.

The developer is normally diluted with two volumes of water, and the time of development is some two minutes. Exposure and dilution may be varied as with the preceding formula, with the same results.

A print of softer gradation is obtained by using:

20 – SOFT DEVELOPER

Metol	55 grains	3 grams
Sodium sulphite, anh.	1 ounce	25 grams
Sodium carbonate, anh.	265 grains	15 grams
Potassium bromide	18 grains	1 grams
Water to	40 ounces	1000 ml

The normal development time is about 1½ minutes; to obtain the maximum benefit of the softer gradation – equivalent to nearly one paper grade difference – development should not be extended.

Some increase in contrast is also possible with a strongly alkaline developer with a high concentration of hydroquinone, for instance the following:

21 – CONTRASTY DEVELOPER

Metol	35 grains	2 grams
Hydroquinone	180 grains	10 grams
Sodium sulphite, anh.	2 ounces	50 grams
Glycin	200 grains	11 grams
Sodium carbonate, anh.	3 ounces	75 grams
Potassium bromide	95 grains	5·5 grams
Water to	40 ounces	1000 ml

Various methods of two-bath development have been suggested from time to time, in which the print is first developed in the soft working metol developer, followed by treatment in the contrasty developer. The print gradation can be varied by varying the development time in the two solutions.

In practice the contrast control offered by this method is neither particularly versatile nor very predictable. It is true that the two developers, No. 20 and No. 21 above, represent an overall contrast difference in the finished print equivalent to about 1 to 1½ paper grades. Such a method is of possible use if a more contrasty or softer paper grade is not immediately available. Otherwise the use of an extended range of paper grades (or a variable contrast paper) is far more convenient than working with two developers – not to mention the fact that the trial-and-error nature of contrast variation by development makes any rational working (based for

instance on exposure measurement on the baseboard) impossible.

These methods are therefore strictly for the amateur who has the inclination – and the leisure – for experimenting in the darkroom, possibly to give a print just a little more or just a little less contrast intermediate between two existing paper grades. (Even there variable contrast papers lead to the same result more simply. In commercial printing where it is expedient to work with only one paper grade, contrast variations are obtained by flashing – page 106).

AMIDOL DEVELOPER

Amidol used to be very popular as a developing agent for bromide papers, since it gives pure black tones and can be made up particularly easily and cheaply. At the same time, a correctly designed metol-hydroquinone developer produces just the same results, and keeps very much longer in solution. For this reason amidol developers are not available as ready made-up solutions. The following formula is typical:

22 – AMIDOL DEVELOPER

Sodium sulphite, anh.	1 ounce	25 grams
Potassium bromide	18 grains	1 gram
Water to	40 ounces	1000 ml
When dissolved, add:		
Amidol	90 grains	5 grams

The sodium sulphite stock solution can also be made up in four times the above concentration and diluted when required. The amidol may be pre-weighed in small glass phials and added immediately before use. The solution decomposes rapidly and is best thrown away after an enlarging session.

EXHAUSTION AND KEEPING QUALITIES

Developer stock solutions should be stored in full and well stoppered bottles. Under these conditions an unused print developer – for instance Formulae Nos. 12 to 16 on page 334 – can be expected to keep at least two to three months. An unopened bottle of a commercial developer solution has a shelf life of at least six months and sometimes even longer. (Many of these developers are available in much more concentrated form for dilution 4–8 times.) Once the bottle has

been opened, and is half empty the developer deteriorates more rapidly and 1–2 months may be recommended as a limit. It is generally advisable to transfer stock developer from a half-full bottle to a bottle of smaller size.

The processing capacity of developers varies with the concentration – i.e. the strength of the active ingredients – and to some extent the conditions of use. It depends also considerably on the quality deterioration regarded as acceptable. As the developer gets exhausted, the required exposure time for good print quality increases before any serious deterioration of image tone sets in. In professional printing practice, where exposure measurement in enlarging has to be based on standardised processing, the exhaustion limits are rather stricter, because the development time required in an exhausted developer also increases. The operator who himself develops every print by inspection, can carry on for a time with increased length of development. Table XX below gives the approximate capacity of the developers listed in Table XIX on page 334, at their recommended dilution.

XX – AVERAGE CAPACITY OF PRINT DEVELOPERS

Nominal Print Size		*Approximate Number of Bromide Prints Developed by*		
in.	*cm*	*1 litre* (35 *ounces*)	*1 gallon (Imp.)* (4·5 *litres*)	*1 gallon (U.S.* (3·8 *litres*)
$3\frac{1}{4} \times 4\frac{1}{4}$ 4×5	8×11 9×12	35–90	140–400	120–340
$4\frac{3}{4} \times 6\frac{1}{2}$ 5×7	12×16 13×18	17–45	70–200	60–170
$6\frac{1}{2} \times 8\frac{1}{2}$ 8×10	16×21 18×24	8–20	35–100	30–80
10×12	25×30	6–15	25–65	20–55
11×14 12×15	28×35 30×40	3–9	15–40	13–35
16×20	40×50	2–5	9–25	7–20

These figures apply to bromide papers. The lower figure in each range is a thoroughly safe lower limit for professional darkroom work, based on no loss of quality and no noticeable change in development characteristics. The higher figure is adequate where prints are developed in such a way that slight exhaustion can be compensated by increased developing time. As will be seen, the gradual exhaustion without loss of quality but with need for developing compensation extends appreciably.

The figures in Table XX apply to conditions where prints pass through the developer fairly continuously – i.e. where deterioration of the solution by standing is negligible. If the developer stands in the open dish for long periods while prints pass through very intermittently during an enlarging session, aerial oxidation reduces the developing capacity.

These values are thus mainly intended for processing on a more commercial scale, to indicate how often the solution needs changing. In large-scale processing it is often customary to replenish the developer in a tank by adding controlled quantities of a concentrated replenisher, and the formulae used are designed for such replenishment. For print processing on a smaller scale solution renewal is usually carried out more empirically – the developer in the dish being thrown away when the required developing times become noticeably longer. Even there the solution should be discarded well before any visible deterioration of image colour in the prints sets in.

Used developer does not keep well and for home enlarging it is best to prepare the approximate quantity of solution likely to be needed for a session and throw it away afterwards.

ACTIVATORS FOR RAPID PROCESSING

The activator used in roller processors for stabilization papers is basically a caustic alkali solution with usually certain additives. Since developing agent is incorporated in the paper emulsion, the activator as such is not subject to oxidation and will keep almost indefinitely in closed bottles. The bottles in which the solution is supplied are usually plastic – not only to reduce the risk of breakage, but because the caustic alkali solution gradually attacks glass.

In the processing tray in the machine the activator gradually loses strength by absorbing carbon dioxide from the air, which turns the caustic alkali into alkali carbonate. The first sign of this loss of activity is that prints need increased exposure (with the roller processing machine increased development is impossible). In the tray of the machine the activator can be expected to remain usable for about a week; after this, or whenever prints are found to need extra exposure, it should be discarded.

In continuous use, exhaustion as such is slower than actual consumption of the solution by being carried over into the

stabiliser bath. So there the activator can be kept up to strength by periodic or automatic topping up (see also page 233).

In use the activator also goes brown. This is due to hydroquinone dissolved out of the paper emulsion which then oxidises in the activator tray. Such browning does not seriously affect the working of the solution, but if it becomes very strong it may lead to staining – especially if the stabiliser is also getting near exhaustion.

If a roller processor is used intermittently, it is best to drain off the solutions back into their storage bottles. Used activator tends to throw down a sediment on keeping; this should be filtered off before re-use. The main danger is that solid particles may be picked up by the rollers of the machine and cause spots or prevent uniform action of the solution on the print surface.

A further risk of keeping solutions in a roller processor for long periods is evaporation from the chemical-moist rollers resulting in crystallisation of some of the components. More solution then seeps onto the rollers by capillary action until a sizeable solid deposit builds up. This can damage the material of the rollers when the machine is started again and invariably also causes spots on the prints.

Even when the roller processor is emptied it is advisable to run it periodically (every few days) for a few seconds to prevent the formation of flats on the rollers due to continuous pressure on just one part of the circumference in contact with the neighbouring roller. Such flats also lead to uneven action during processing and can create regular darker lines across the print where a greater quantity of activator is in contact with the emulsion surface during part of the roller rotation.

Fixing, Washing and Drying

After development, black-and-white prints must be thoroughly rinsed before they are placed in the fixing bath. It is more satisfactory to use a stop bath between the developing and the fixing baths.

STOP BATHS

The function of the stop bath is to arrest immediately the process of development, so that it cannot continue and possibly cause stains. This risk is present especially when handling large prints whose wet surface remains exposed to the air for a longer time during transfer from one dish to the next, and which are thus more liable to aerial oxidation of any developer carried over if a plain water rinse is used. For small prints a brief water rinse is adequate, since the acidity of the fixing bath quickly neutralises the developer.

The acid stop bath instantly neutralises the alkali of the developer which is absorbed by the print, and prevents it from causing spots on the image. The acid stop bath also protects the fixing bath against premature deterioration.

A stop bath is less essential with plastic coated prints, especially in roller processors, where the amount of developer carried over into the fixer is greatly reduced by squeegee rollers. There an acid fixer is fully adequate and the stop bath can be eliminated altogether, especially as that reduces the time the paper spends in processing solutions (see also page 326). The following points thus apply more to traditional papers without plastic coating.

The stop bath consists of a 2 per cent solution of glacial acetic acid, or a 4 per cent solution of potassium metabisulphite or sodium bisulphite. Stronger acids (for instance hydrochloric) must not be used, because they interact with and decompose the chemicals in the fixing bath. Nor should the stop bath be any more concentrated than indicated here, or the print left in it for too long.

A stop bath also gets exhausted by the alkali carried over

into it from the developer, which gradually neutralises the acid present. A simple test is to dip a strip of blue litmus paper into the stop bath: if the paper does not turn bright red, the stop bath is no longer active.

Some commercial stop baths incorporate an indicator dye which is yellow as long as the bath is sufficiently acid, and turns purple when the acid has been neutralised. This colour change is particularly obvious in the yellowish or orange darkroom illumination, and gives an automatic and immediate indication that the stop bath needs renewing.

FIXING

Fixing is an essential part of the positive process, since it removes from the image all the unexposed and undeveloped silver salts remaining there. The essential chemical used to dissolve these silver salts is sodium thiosulphate, commonly known as hypo.

When the print is first immersed in the fixing bath, a complex double thiosulphate of sodium and silver is formed. This double compound is barely soluble in water, and for this reason is hard to wash out of the print. As the action continues, a different complex substance is formed which very readily dissolves in water. To ensure good keeping qualities of prints, fixing must therefore go on long enough for the barely soluble compound to be changed into the readily soluble one.

Fixing baths for papers are usually acid, to arrest the action of any developer carried over if no acid stop bath is used. The following is a suitable formula.

23 – ACID FIXING BATH FOR PAPERS

Sodium thiosulphate, cryst.	8 ounces	200 grams
Potassium metabisulphite (or sodium bisulphite)	265 grains	15 grams
Water to	40 ounces	1000 ml

Normal fixers, other than rapid fixers (page 344) are generally available commercially as ready-mixed powder, but not in prepared solution form. The powder therefore has to be weighed out, and this must be done outside the darkroom, for chemical dust from fixing salts is particularly liable to cause spots if it settles on enlarging paper prior to develop-

ment. Since the weighing need not be very precise, it is usually more convenient to measure the powder by volume. Suitable measures are often supplied with the fixing salt packings or available separately.

The measured out volume of powder is poured through a dry funnel into a stock bottle of the required volume, which *is already three-quarters filled with water*. Top up to the final volume, pouring the water through the same funnel to wash away any remaining powder, and securely stopper the bottle. Invert a few times during the next few hours until the fixing salt is fully dissolved. This fixer is thus best prepared some time before it is needed.

When making up a fixer from fixing powder for immediate use, always pour the powder into water while stirring the latter, and never pour the water on top of the powder. Commercial fixing powders use the sodium thiosulphate in anhydrous form; if water is poured on top of the powder this cakes together into a solid mass which takes very long to dissolve.

RAPID FIXERS

As already indicated, plastic coated papers should not spend too much time in processing solutions to avoid absorption of water through the edge of the paper. Rapid fixers containing amonium thiosulphate are thus recommended in place of the traditional sodium thiosulphate fixer. But even with older type enlarging papers they have significant advantages.

Firstly, ammonium thiosulphate is much more soluble in water than the sodium salt. Hence such fixers can be made up as concentrated stock solutions and diluted up to 10 times for use. So it becomes practical for the amateur with limited darkroom and chemical handling facilities to stock the fixer in liquid form instead of making it up from powder.

Secondly, as the double silver ammonium thiosulphate complex is more soluble than the corresponding sodium salt, the fixer tolerates a higher concentration of dissolved silver salts before fixation becomes too slow or incomplete. Therefore the fixing capacity of ammonium thiosulphate fixers is appreciably greater (double or more) than that of corresponding sodium thiosulphate formulae.

On the debit side is the fact that the high-speed fixer also

attacks the silver image – especially highlight details – more rapidly if fixing times are prolonged. For this reason even non-coated prints should not spend more than a maximum of 2–3 minutes in an ammonium thiosulphate fixer.

Fixing baths of this type must always be acid, for the ammonium thiosulphate decomposes if the fixer becomes alkaline, giving off unpleasant ammonia fumes.

FIXING TIME

Prints take about 30 seconds to fix fully in a rapid fixer with ammonium thiosulphate. In more traditional sodium thiosulphate fixers the actual fixing time is still fairly short, because papers contain a much lower coating weight of silver salt than the emulsion of a negative. The main process of fixation is virtually complete within half a minute with chloride papers and about 1 minute with bromide papers, but it is safer to leave prints in the fixing bath for 4 to 5 minutes. They must be moved about in the fixer for the first couple of minutes to ensure that the solution has full access to the emulsion surface. This, as also the following remarks, applies only to traditional papers without plastic coating. Plastic coated papers should always be fixed one at a time, moved about all the time during fixing and removed from the fixing bath, washed (page 350) and dried straightaway.

When working with older papers, prints may accumulate in the fixing dish. But it is a mistake to leave them in the fixer for longer than 7–8 minutes because extended fixing time in a fresh fixing bath may lead to the details in the print highlights being dissolved away, while shadow density is reduced. During prolonged fixing the acid from the fixing bath also soaks into the paper base and becomes so firmly fixed there that it is difficult to remove. The presence of this acid in the print after drying tends to cause deterioration of the silver image as time goes on – another reason why excessively long fixing times are undesirable.

Prints should not be allowed to lie on top of each other in the fixer, for in this case the solution cannot get to their surfaces evenly. Stains may then appear on the portions which have been covered. These stains may occur either during fixing or after the print has been dried and mounted.

EXHAUSTION OF FIXING BATHS

To ensure permanence in prints a fixing bath must not be

used to its ultimate limits of service. A fixing bath becomes exhausted in four ways:

(1) The removal of hypo from the fixer as prints are taken out for washing, and the carrying in of liquid from the intermediate rinse or stop bath gradually reduces the actual hypo concentration in the fixer.

(2) The chemical process of fixation uses up the hypo itself by the formation of the complex sodium silver thiosulphates.

(3) As the concentration of silver salt in the fixer increases, the latter becomes less able to convert the slightly soluble complex thiosulphate into the more soluble kind. Where much silver is present, it also tends to be absorbed into the paper base of the print, from which it cannot be readily removed by washing. The presence of these silver salts, which are still slightly sensitive to light, leads to subsequent staining and deterioration of the image.

A rise in silver concentration is harmful even if the bath still contains plenty of free hypo; for that reason more concentrated fixing baths do not necessarily last longer.

(4) Where the stop bath is omitted or is allowed to become alkaline through carried-over developer, the acid of the fixing bath also begins to be neutralised. And when the bath becomes alkaline, carried over developer may cause stains and chemical fog through oxidation. The same difficulty is liable to occur where the fixing bath is contaminated with developer solution. (This again applies primarily to prints without plastic coating; PE-type papers should be processed without a stop bath – page 342.)

It is therefore not an economy to use a fixing bath until it refuses to fix further, for hypo is much less expensive than the value of a good print which has been ruined by exhausted fixer.

Table **XXI** on page 347 indicates approximate fixing limits as recommended by the manufacturers of photographic materials. The figures are on the conservative side, but at least they are safe – and this kind of "insurance" is essential in the professional printing darkroom.

Because of the accumulation of silver in the dissolved fixer, no replenishment of fixing baths is advisable. In commercial darkrooms used fixer is however frequently collected for subsequent recovery of this dissolved silver, which on such a scale becomes economical.

XXI – AVERAGE CAPACITY OF PRINT FIXERS

Nominal Print Size		Approximate Number of Bromide Prints Fixed by		
in.	*cm*	*1 litre (35 ounces)*	*1 gallon (Imp.) (4·5 litres)*	*1 gallon (U.S.) (3·8 litres)*
$3\frac{1}{4} \times 4\frac{1}{4}$ 4×5	8×11 9×12	100–200	440–540	380–440
$4\frac{3}{4} \times 6\frac{1}{2}$ 5×7	12×16 13×18	50–60	220–270	190–220
$6\frac{1}{2} \times 8\frac{1}{2}$ 8×10	16×21 18×24	25–30	110–130	90–110
10×12	25×30	16–20	65–90	60–75
11×14 12×15	28×35 30×40	12–15	50–65	45–55
16×20	40×50	6–7	25–32	20–25

A freshly mixed fixing bath of the composition given on page 341 (Formula No. 23) keeps virtually indefinitely since there is no oxidation to worry about. It is however still best kept in a stoppered bottle. Fixing baths containing hardening and other additives (page 349) may deposit a precipitate, especially if the acidity is low. The dissolved silver salts in a partly used fixing bath gradually decompose, forming a blackish sludge of silver. This should be filtered off before the bath is used again.

THE USE OF TWO FIXING BATHS

With older non-coated papers, two-bath fixing avoids overworking the fixer. This merely involves an extra processing dish on the wet bench, containing a second fixer similar to the first one. During the processing the prints go into the first fixing bath and are transferred, after 4–5 minutes, to the second fixing bath where they remain a further 3–4 minutes. The first bath thus does the main work of fixing, while the second one removes any traces of silver salts still left in the emulsion. The first bath gets exhausted in the normal way, while the second stays fresh much longer.

When the first bath has fixed the appropriate number of prints it is discarded, and the second bath takes its place. This in turn is replaced by a fresh second bath. In this way no more fixer is needed for thorough fixing, but the virtually fresh second bath ensures that all prints are fully fixed even when the first bath nears the end of its useful life.

NEGATIVE AND PRINT FIXING BATHS

It is not advisable to use the same fixing bath for both negatives and prints. Films and plates can be fixed out perfectly well in a solution which is so full of silver that it would stain any print put into it. And the film base does not absorb and retain unstable silver salts in the same way as a paper base. But even with plastic coated papers, negative fixing baths should not be used for prints.

Many films also have a coloured backing layer which may not be entirely bleached when it is dissolved in the fixing bath. To some extent this may again tend to colour the paper base of prints.

STABILISATION

The stabiliser employed in stabilisation processing does not fix prints in the normally accepted sense – i.e. dissolve out all unexposed silver salts. Instead it converts the silver into complexes which are virtually insensitive to light and so sufficiently stable to remain in the emulsion. Such colourless and stable silver complexes are formed by ammonium thiocyanate, thiourea and certain other compounds. These form the basis of most commercial stabiliser baths.

The stability of some of these complexes formed in the emulsion depends also on the presence of excess stabiliser and of the more soluble products of the stabilisation process. For this reason a stabilised print should not be washed afterwards, since this may remove such soluble compounds and reduce the keeping qualities of the stabilised print.

Stabilisers in roller processors become exhausted partly by the activator carried over into the bath and partly by the removal of liquid absorbed into the paper emulsion. The maker's instructions should therefore be consulted for the maximum number of prints which may be treated in a given volume of stabiliser.

A stabilised print is not as permanent as a properly fixed one. If thoroughly dried immediately after processing and kept in a dry atmosphere away from constant exposure to light, it should however last several years without deterioration. (A print fixed in an exhausted conventional fixer will deteriorate much sooner.) For maximum permanence a stabilised print can be refixed in an ordinary acid fixer, followed by the normal processes of washing and drying. It

will then be as permanent as a print processed in the orthodox manner.

Stabilisation papers are not available in plastic coated form, and where full permanence is essential the accelerated processing procedure already described is quicker overall than stabilisation processing followed by refixing, rewashing and redrying. That is a further reason why plastic coated papers and their accelerated processing – especially in roller processors – are rendering stabilisation systems obsolete.

HARDENING FIXING BATHS

Plastic coated papers must not be dried at too high a temperature (page 358) because this adversely effects the plastic coating. Traditional non-coated papers can be heat dried (and glazed) provided the gelatine emulsion is toughened by treatment in a hardening fixing bath. Many proprietary fixing baths include a hardening agent; a hardening fixer can also be made from a plain acid fixer by adding one part of the following hardening solution (Formula No. 24) to 10 parts of the fixing bath (No. 23) on page 343.

The fixer and the hardening solution keep well separately, but not so well once they are mixed. For this reason it is best to keep the hardener always separate until required.

A similar hardening solution can be added to a rapid fixer based on ammonium thiosulphate. Again the solutions should not be mixed until required.

24 – HARDENING ADDITIVE

Solution A		
Water	40 ounces	1000 ml
Sodium sulphite, anh.	4 ounces	100 grams
Glacial acetic acid	4 ounces	100 ml
Solution B		
Water	10 ounces	250 ml
Potash alum	4 ounces	100 grams

To make solution A, dissolve the sodium sulphite in warm water and then add the acid. Mix the two solutions when they are completely cold.

When adding the hardener to the fixing bath, both must be cold, i.e. below about 70°F (21°C). Otherwise interaction between the two may form a cloudy precipitate.

Chrome alum is also used as a hardener in fixing baths. This however does not keep its hardening activity in solution for longer than a couple of days.

ALKALINE TREATMENT AFTER FIXING

The paper base of a print without plastic coating tends to absorb and retain acid components of the fixing bath. To eliminate all acid from the paper a post-fixing alkali bath is advisable. This is simply a 1 per cent solution of sodium carbonate, and the print is immersed in this, after fixing and a brief rinse, for 2–3 minutes. This treatment will make the print much easier to wash thoroughly and should always be used when any aftertreatment such as toning is intended, since it eliminates many of the possible sources of failure in such processes.

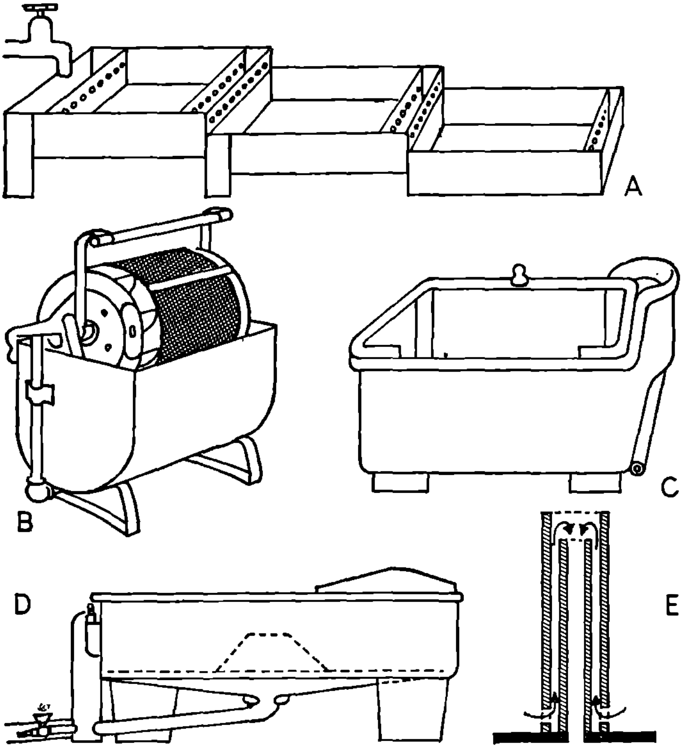
WASHING

A print is washed in order to remove all the remaining silver salts which have been dissolved by the fixing bath. If these salts are not removed, the image will tend to turn yellow in the course of time.

Like the other processing steps with plastic-coated papers, washing should be – and can be – short. For as the sealed-in paper does not soak up any water, washing has to remove chemicals only from the very thin emulsion layer. In running water such prints can be washed in as little as 2 minutes and rarely need more than 5 minutes.

An important requirement is thorough water circulation to carry away all chemicals as soon as they diffuse out of the emulsion layer. For a dish-processing set-up a special dish with water running in fairly vigorously from a tube or hose is adequate. The end of the tube should have some means of distributing the water throughout the dish. If the latter is slightly tilted in a sink or basin, the overflowing water runs off evenly and rapidly. Suitable nozzles for such a dish arrangement are available commercially. The water flow should be about 4 to 5 litres/minute; this is quite rapid, but as the water only has to be turned on during the two to three minutes the print spends in the dish, the actual water consumption is not excessive. Roller processors with their own washing section similarly need a direct running water

WASHING APPARATUS



In the cascade washer (A) prints are placed in the bottom division first, then after an interval raised to the middle and a fresh batch of unwashed prints replaces them. Finally the washing is finished in the top with the fresh and uncontaminated water. Each stage requires 5–10 minutes, and hence the complete washing 15–30 minutes.

In the drum washer (B) the prints rotate inside a drum kept turning by the inflowing water driving against a turbine arrangement. In the tank washers (C and D) the water enters in jets and keeps the prints circulating. The water may be drained off either by a siphon or a central outflow below a perforated base (as in D).

A simple siphon (E) can convert a normal hand basin into a print washer on being placed over the outflow. As the water reaches the level of the top of the siphon, it drains off from the bottom. The prints must however be stirred around periodically by hand.

All the above arrangements are intended for traditional papers without plastic coating that require lengthy washing. The handling time involved in charging and emptying is much too long for plastic coated papers which are best washed singly. One step of the cascade washer (A) can however be used provided the water flow is suitably speeded up.

supply. This makes roller processors of this kind less suitable for amateur darkrooms without running water.

Washing is more cumbersome with non-coated papers, because it has to completely remove all chemicals absorbed in the paper base as well as in the emulsion. This is what makes this the longest step in conventional print processing – the average time required for washing in running water is about half an hour and still 15–20 minutes if an alkaline carbonate bath is used after fixing.

The requirements of washing older types of bromide paper are determined by two factors:

(1) The need for constantly carrying away water laden with chemicals that have diffused out of the print, and

(2) The need for continuing this long enough to get rid of all the slowly diffusing chemicals without an excessive water consumption.

The water flow in conventional print washing is therefore kept comparatively low which makes efficient systems of removing chemical-laden water more important. For that reason running water into a dish at one end and letting it run out at the other is not so efficient, because such a process can sweep away chemicals only with a vigorous water flow. A better way is to introduce the water at the bottom of the dish or tank with a rubber hose to ensure that chemical-laden water cannot collect in one place, and keep the prints moving during washing. (That again is taken care of with a strong water flow when washing plastic-coated prints.)

A further point with non-coated papers is that in view of the long duration of the washing step prints must be washed in batches. It then becomes all the more necessary to ensure maximum print movement in the water and efficient drainage of spent water without an excessive water flow. The following set-ups are designed with this end in view for prints on an unprotected paper base.

On an amateur scale washing can be carried out in a sink or basin, provided the prints are kept moving and the water continuously drained away from the bottom. For this purpose a simple siphon drain can be fitted over the plughole of the sink, and the water allowed to run in from the tap.

For work on a more professional scale a print washer is advisable which automatically moves the prints in the water

as well as changing the water itself. Three main forms are:

(1) *Drum Washers,* in which the prints are placed in a perforated drum and the latter is kept turning during washing. The drum dips into a basin which is continually emptied by a siphon arrangement.

(2) *Siphon Washers,* where water streaming into a tank keeps prints in motion, and the tank empties at regular intervals by means of an automatic siphon. Some versions hold the prints in frames or racks which are kept rocking by the inflow and outflow of the water.

(3) *Cascade Washers,* consisting of a series of trays arranged at different levels. Water flows from the tap into the top tray, empties from there into the second tray and then thence into a bottom tray from which it drains to the waste. Prints are here washed in stages, a batch being introduced into the bottom tray first. After an interval the prints are raised to the middle tray and a fresh batch of unwashed prints into the bottom tray. The washing is finished in the top tray with fresh and uncontaminated water. Each stage requires about 10 minutes, so that complete washing takes 30 minutes.

WASHING WITH LIMITED WATER SUPPLIES

Running water is obviously ideal for washing prints, provided it is freely available. The above methods are however somewhat wasteful for traditional unprotected papers requiring protracted washing. Such prints can be washed efficiently in comparatively small amounts of water by using changes of water.

The basis of this method is that successive dilution of soluble chemicals carried over in a print emulsion can very quickly reduce the chemical concentration to a harmless level. If for instance we have a batch of prints which have carried over with them 100 ml of fixer solution containing 20 per cent hypo, and place them in a dish of 1000 ml water, the carried-over solution is eventually diluted 10 times. If the prints are moved about all the time, this may take 3 or 4 minutes. If this water is then poured away and the prints placed in 1000 ml of fresh water they will have carried over (assuming again that they hold 100 ml of solution) 2 grams of hypo. In this second change of water

this is again diluted 10 times, and after five changes of water will contain between them only 0·2 milligram of hypo.

If the batch consisted of say a dozen 20 × 25 cm or 8 × 10 inch prints (for which a carry-over of 100 ml is generous), the prints will after the last change of water contain only 0·033 microgram of hypo per square cm – well below any harmful level. Residual silver salts are eliminated in the same ratio. Yet the whole washing process has taken only 5 litres, or just over 1 gallon, of water.

The amount of water used can be reduced still further by making the water volume at each change smaller and increasing the number of changes. Thus seven changes, using 500ml of water each time, will reduce the residual hypo to approximately the same level as five changes of 1000 ml – yet use only 3½ litres of water. (But this kind of saving would be significant only in dire emergencies.) Washing in running water is in effect equivalent to using changes of very large volume, if we regard the complete renewal of the water in the washer or basin as a "change". If the water is changed faster than the soluble salts can diffuse out of the emulsion, then washing prints in a bath or with a strong stream of water does not increase the efficiency of washing, but only the water consumption.

For this reason a comparatively small print washer which ensures rapid agitation of the prints and empties itself once every 3 or 4 minutes is still the most economical way of print washing even in running water.

From this follow two rules when washing prints in changes of water:

(1) The prints must be thoroughly moved about in each change to ensure that the absorbed soluble salts have plenty of opportunity to diffuse out of the emulsion and paper base.

(2) Prints should be drained as thoroughly as possible between transfer from one change of water to another. The smaller the amount of liquid carried over, the more effective the dilution at each change.

WASHING IN SEA WATER

The use of sea water for washing photographic materials is practicable only when the prints can receive a final wash of about 5 minutes in fresh water. This final wash removes the residual salts from the material and thus prevents rapid

fading of the image caused by these salts in the presence of hypo, and absorption of moisture by the common salt retained in the print.

In fact the removal of hypo is greatly accelerated during washing in sea water as compared with fresh water. Prints can therefore be washed in sea water for about one half of the usually recommended time, and finally for about 5 minutes in fresh water. The total time involved in washing in sea water followed by fresh water is thus somewhat less than required by fresh water alone.

An increase of 10–20°C in the temperature of the sea water increases the rate of washing by 25 to 50 per cent. But washing at a temperature as low as 50°F (10°C) still removes the hypo more rapidly than fresh water at 70°F (21°C).

TESTS FOR FIXING AND WASHING

Fixing has to convert, as we have seen, all silver salts not reduced to metallic silver in the emulsion into a soluble form, and washing has to remove these soluble salts. Both are important for the permanence of the image. If fixing has been incomplete, washing can in certain circumstances actually reduce the stability of the image by removing the excess of fixing chemical which keeps partially converted silver thiosulphate complexes in a stable form. This is also the reason why prints must not be washed after stabilisation processing (page 348).

Complete fixation as well as complete washing can be tested – after washing – by the following methods. They apply primarily to older uncoated papers using longer fixing and protracted washing methods. For plastic coated papers they do however provide a check on whether the fixer is exhausted and on whether the shortened washing procedure is adequate – they are not envisaged as a routine test for every print!

To test for fixation, prepare a 20 per cent sodium sulphide solution. (This has an unpleasant smell of hydrogen sulphide which is extremely harmful to unexposed photographic materials, and should therefore be kept well away from the darkroom.) For the test itself dilute 1 part of this with 9 parts of water.

Take a strip of unexposed paper which has not been developed, and fix and wash it simultaneously with other

material. After washing immerse the strip in the sodium sulphide solution. Any trace of silver salt in the paper will produce a brown coloration.

This test is also useful in that it can indicate when the fixing bath is exhausted, and insoluble silver salts remain in the paper. In this case the strip of fixed and washed paper is divided into two. One part is tested when washing should be complete. If discoloration occurs, continue washing for another 15 minutes and test the second strip. If this still shows the discoloration, the fixing bath is not working properly and must be replaced by a fresh one. All the material which was being washed must then be refixed and washed again.

To test for washing, again process with the batch of prints an unexposed white sheet of photographic paper of the same weight and size as the majority of prints in the batch. After the final wash cut off a strip of this sheet and immerse it in a 1 per cent solution of silver nitrate for about 3 minutes. Then rinse in water and compare, while wet, in subdued daylight or artificial light with the wet untreated portion. If the hypo has been completely removed, no colour difference should be visible. A yellow-brown tint indicates the presence of hypo in the print. As long as the tint is very pale, washing can still be considered adequate. A stronger tint indicates inadequate washing.

Commercial hypo test solutions and kits are available which work on the same principle.

THE ELIMINATION OF HYPO

While thorough washing should in theory reduce the level of residual hypo in a print to a negligible figure (page 350) it is virtually impossible to remove the last traces of hypo from photographic papers by any known procedure of washing. This is partly because the paper base retains a certain amount of hypo, especially if the print has been fixed for a long time in an acid fixing bath. Even washing for as long as 20 hours does not eliminate the final trace of hypo in either single or double weight papers. The sulphur in the residual hypo tends to combine sooner or later with the silver image to form yellowish brown silver sulphide. The image then appears to fade.

The safe level of residual hypo depends on the nature of

the silver image, while the amount of hypo retained depends on the paper base. This safe level is higher with the comparatively coarser grained silver image in a bromide paper than for the finer grained image of a chloride paper. Also, as might be expected, a double weight paper base retains more hypo than a single weight base. Complete elimination is in fact only possible with plastic coated or otherwise waterproofed enlarging paper bases. For those the following remarks obviously do not apply.

As long ago as 1940 *J. I. Crabtree, C. T. Eaton* and *L. E. Muehler* of the Kodak Research Laboratories showed that the residual hypo level when washing prints was safe only with single weight bromide papers, but not with either chloride papers or double-weight bromide papers. These authors also recommended a hypo eliminator without the drawbacks of earlier hypo elimination methods which tended to leave substances in the material as harmful as hypo. This hypo eliminator consists of two volatile substances, hydrogen peroxide and ammonia. It oxidises the hypo to sodium sulphate which is inert and soluble in water, while any excess eliminator evaporates on drying.

Wash the prints in the usual way, and at the end of the washing time immerse each print for about 5–6 minutes at 70°F (21°C) in the hypo eliminator solution. During this process bubbles of oxygen are given off. Finally wash for a further 10 minutes before drying. About ten 20 × 25 cm or 8 × 10 inch prints or their equivalent can be treated in 1 litre of the solution.

For commercial photofinishing use a more concentrated eliminator is recommended, made up by using four times the above amount of hydrogen peroxide solution. The prints are washed for about 15 minutes, immersed for about 5 minutes

25 – HYPO ELIMINATOR

Water	20 ounces	500 ml
Hydrogen peroxide, 3% solution (commercial 10-volume solution)	5 ounces	125 ml
Ammonia, 3% solution	4 ounces	100 ml
Water to	40 ounces	1000 ml

Instead of 10 volume hydrogen peroxide half the quantity of 20 volume solution can be used. The 3 per cent ammonia is made up by diluting one part of 0·880 ammonia with nine parts of water.

in the hypo eliminator solution and finally washed again for 10 minutes before drying.

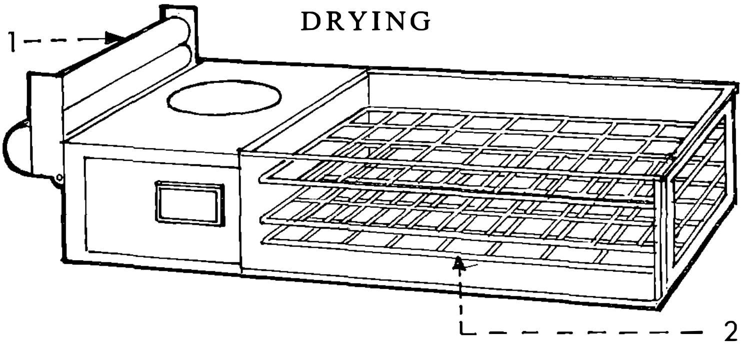
DRYING PLASTIC-COATED PAPERS

Plastic-coated papers can be dried by hanging them up by clips or placing them face down on a clean cloth. This is somewhat slow – unless prints are already squeegeed half dry on emerging from a roller processor – and takes on the average about 20 minutes. The difficulty with such methods is that as prints accumulate at the end of processing, it is cumbersome to have to provide drying space and even more cumbersome to have to clip or pin up prints one by one as each enlargement leaves the wash. Some form of heat drying is therefore more efficient and convenient.

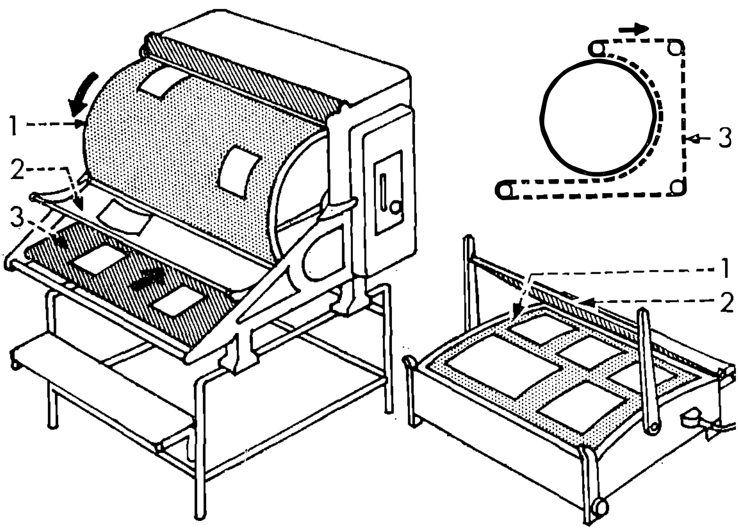
Before any form of accelerated – or even natural – drying, plastic-coated papers should first be squeegeed, as spots of water on the surface affect the surface gloss. A simple way of drying is to hold the print in front of an ordinary radiator (or better still a warm air blower) for a minute or two. For more convenient operation various print driers are available specifically for plastic-coated papers. They usually consist of a pair of squeegee rollers that feed the paper into or through a drying section where they are exposed to a stream of warm air or even to microwaves. In simpler driers the prints may be placed, after squeegeeing, onto racks in the drying chamber. Such a drier may hold anything up to half a dozen prints and dried them in 4 to 5 minutes. When the drier is full, the first-inserted print can be removed dry every time a fresh print is ready for drying. Automatic roller driers with warm air and radiant heat can dry plastic-coated prints in as little as 30 seconds.

The most convenient drying temperature is around 60 to 70°C; excessive heat as in hot glazers for traditional, non-coated papers should be avoided as this can affect the plastic coating and lead to uneven surface quality.

Glossy plastic-coated prints must never be dried in contact with a hot glazing surface. During drying, such an arrangement does not allow efficient escape of moisture which is trapped between the glazing surface and the impermeable plastic-coated paper support. Glossy plastic-coated papers yield a sufficiently high glaze in normal drying; this falls a



A simple drier for plastic-coated papers squeegees the print through the rollers 1; they are then placed on racks 2 in a compartment fed by warm air.



Glazing machines. The rotary glazer (*left*) consists of a large heated drum with a polished surface. Prints are fed face up (for glazing of glossy papers) or face down (for drying of matt papers) on the apron 3 which brings them in contact with the drum 1. After one revolution the prints drop off into the receiving tray 2. In the flat bed glazer (*right*) prints are placed on the heated glazing sheet 1 and pressed into contact by a tensioned apron 2.

little short of the quality of conventionally glazed non-coated prints but is adequate for all purposes where glossy prints are needed – especially for reproduction in print. Generally, the faster plastic-coated prints are dried (with the aid of radiant heat and/or warm air) the higher the surface gloss.

Plastic-coated papers can be dried on hot bed driers and glazers intended for traditional papers, provided that the emulsion surface is never allowed to come into contact with the heated surface. The temperature of such driers should also be reduced.

With earlier types of varnished water proof papers – which have many of the advantages of plastic-coated papers – the drying temperature is more critical since the varnishes have a lower melting point.

One great advantage of resin or plastic-coated papers over the older non-coated type is that they do not curl appreciably during drying. There is thus no need for straightening prints afterwards.

DRYING NON-COATED PAPERS

The method of hanging non-coated prints up to dry on clips, or placing them face down on a clean cloth, is rarely satisfactory. Prints dried in this way seldom remain flat, and must be straightened by stroking the backs with a ruler or pulling them over the edge of a table. The most convenient method is to dry prints in a hot-bed drying press, which can also be used for glazing (page 362).

Where no glazing is intended, the prints are placed face up on the heated surface. Remove superficial moisture from the emulsion surface with a fluffless cloth, a viscose sponge or a piece of photographic blotting paper. Then stretch the apron of the drier over the prints. Heat drying takes some 5–10 minutes, but the press should not be too hot, especially with matt and semi-matt papers. Excessive heat increases the glossiness of the emulsion surface and also causes large prints to come out with wavy edges. The main reason for this is however an insufficiently tensioned apron or cloth over the prints. Brown stains on heat dried prints are invariably due to insufficient washing after fixing.

Warm-air and heated roller driers for plastic-coated prints can also be used for non-coated papers but drying

there takes a little longer while the water is driven out of the paper fibre as well as the emulsion layer. But high temperature units of this type can dry traditional papers in a minute or two.

Even non-coated papers are hardened to stand up to heat treatment without risk of melting the emulsion. The use of a hardening fixer increases this protection. If any trouble is experienced, the prints may be treated in a preliminary hardening bath before drying by heat. A useful bath for this purpose consists of:

26 – HARDENING BATH

Water	40 ounces	1000 ml
Formalin, 40% solution	6 ounces	150 ml

Prints are bathed in the solution for 5 minutes and then rinsed in plain water before drying.

If drying is not carried out in a press, the prints may be laid to dry, face down, on a piece of clean cheese cloth or muslin tacked to a wooden frame. Remove all superfluous water by blotting off, before drying. The presence of drops of water may result in local irregularities in the surface appearance.

Stabilisation processed papers emerge from roller processors in a semi-dry condition, since the paper base does not have a chance of absorbing much liquid during the rapid passage through the stabiliser bath. Such prints are best allowed to dry naturally, because heat treatment may cause staining and discoloration. The tendency to this depends on the stabilisation chemicals employed; so a preliminary test is advisable. For the reasons given on page 348, the hardening bath mentioned above should *not* be used in this case.

GLAZING NON-COATED PAPERS

Drying a print on glossy paper in intimate contact with a highly polished surface glazes the print surface, giving it an almost mirror-like smooth finish. Glazing is however suitable only for glossy papers; with semi-matt and other surfaces the surface smoothness may be increased, but is unlikely to be even. Nor, for the reasons already stated (page

358) is glazing of this kind suitable for plastic-coated papers.

There are two methods:

(a) Cold glazing, which takes time but needs no equipment beyond a squeegee and the glazing surface;

(b) Hot glazing, which requires a glazing press but is the only feasible way of dealing with a flow of prints in a professional darkroom.

The best glazing surface for cold glazing is a sheet of plate glass. Next in order of preference are chromium plated and highly polished metal glazing plates. These are also suitable for hot glazing when they are incorporated in a hot bed glazer. Enamelled metal surfaces, so-called ferrotype plates, were at one time fairly widely used but are not very durable.

The secret of success in glazing is an absolutely clean glazing surface. Grease marks (finger prints etc.) on it will result in unglazed areas, while dust and other foreign matter produces specks on the glazed print and may even cause the print to stick to the plate.

To clean the glazing plate, first wash well with soap and water. Then rub over with a cream formed by mixing equal parts of french chalk, methylated spirit (preferably the colourless variety, such as industrial spirit) and 10 per cent ammonia solution (made by diluting 1 part concentrated ammonia with 2–3 parts water). When dry, the white film is rubbed off with a clean soft cloth, and the surface polished until quite clean. Treatment with a 3 per cent silicone solution (I.C.I. M 441) in carbon tetrachloride has also been recommended to reduce the tendency of prints to stick.

Prints to be glazed should have been fixed in an acid hardening fixer. To facilitate glazing, a glazing solution may be used; the need for it depends on how far the paper being glazed has already been pre-hardened. The solution is largely composed of ox gall, but it is simpler (and much more pleasant) to obtain it ready-made than to make it at home.

If a glazing solution is used, the prints are immersed in it straight after washing, just before glazing. The glazing plate is also flooded with the solution.

Lift each print out of the solution by two edges, and hold face down to form a loop hanging down in the middle. Bring the lowest point of the loop into contact with the wet

glazing surface, and gradually lower the edges of the print after it. This will push liquid and air bubbles in front of it until the whole print surface is in contact with the glazing plate. There must be no air bubbles between the print surface and the plate, as no glaze is possible where they are present. With glass glazing plates this is easily checked by looking at the plate from the back.

Then cover the prints on the plate with a thin rubber sheet, and squeegee with a roller type rubber squeegee to drive out surplus water.

Finally blot the plate and prints with a sheet of blotting paper. This is important, otherwise the prints will dry unevenly, giving rise to "oyster shell" markings.

The plates are stood up obliquely against a wall, and left until the glazed prints fall off. It may sometimes be necessary to peel a refractory print from the glazing surface by hand. If a print sticks hard, it is best soaked off and reglazed.

HOT GLAZERS FOR NON-COATED PAPERS

To glaze prints on a flat bed glazer, the chromium plated glazing surface is prepared, and the prints squeegeed down, in the same way as for cold glazing. As it is impossible to check for air bubbles from the other side of the glazing plate, special care is necessary to avoid them when putting the print down on the glazing surface. Have plenty of water on the glazing plate while the prints are lowered down on to it, and squeegee over lightly at first to expel any trapped air. Then cover the prints with the rubber sheet and squeegee firmly into contact with the plate surface.

The chromium plate is placed into the pre-heated hot bed glazer and the cloth apron tensioned on top of the prints. This apron, running over a spring loaded roller, exerts the necessary pressure on the prints to keep them in contact with the glazing plate during drying. This takes about 5–10 minutes, and the press should not be opened too soon. Tapping against the apron with the fingers immediately indicates whether the prints are fully dry and have left the glazing surface.

Flat bed glazers are available in various sizes up to about 45 × 60 cm or 18 × 24 inches and with heating elements up

to about 500 watts. They can handle about 30–40 prints of 20×25 cm or 8×10 inches per hour.

Such a capacity is not sufficient for a professional darkroom, and there a drum type rotary glazer is mainly used. This permits continuous working. Prints are taken direct from the washing tank and fed on to an endless band which conveys them to the drum, against which they are automatically squeegeed by a large rubber roller. The heated drum dries them rapidly while the highly polished chromium plated face of the drum glazes them. The whole operation of drying and glazing usually takes place during less than one revolution of the drum, and the dried and glazed prints fall off the drum on to a tray or another conveyor which takes them to a trimming and sorting station. The speed of rotation of the drum is adjustable to suit different types of papers, for instance to keep double weight prints in contact with the drum longer (to make sure that they are really dry at the end of the cycle) than single-weight prints. Rotary glazers of this kind can handle 80 to 200 prints 8×10 inches per hour.

When a new rotary glazer is being installed, care must be taken to clean the glazing drum so that it is quite free from any protective grease which may have been put on it. The first step is to wash well with a hot solution of sodium carbonate, using a new soft floorcloth for the purpose.

When thoroughly clean and dry, the drum should be well rubbed with a wad of cotton or linen soaked in spirit.

It goes without saying that the surface of the drum must be kept always clean when in use. A daily wash with liquid detergent and water, followed by polishing with a dry cloth should be a standard routine. At longer intervals (weekly in a processing laboratory where the glazer is in constant use) the drum should be polished with a good metal polish applied with cotton wool and cleaned off with a dry cloth. The drum surface must not be cleaned while hot. The glazing surface must also be protected against scratches, which would otherwise appear on every print glazed. For the same reason no abrasives must ever be used.

Use only soft clean cloth for polishing the drum surface and keep the cloth absolutely clean. The same applies to leathers, sponges etc. used for washing the drum. Never put the cleaning material down on a bench or other place where it can pick up dust. Before and after use, wash leathers and

sponges carefully in clean hot water. Any speck of grit taken up by such materials will tend to scratch the glazing surface

When not in use, the glazing machine should be under a dustproof cover. After use, make sure that all parts – including squeegee rollers – are thoroughly dry.

QUICK DRYING OF MATT AND SEMI-MATT PAPERS

Like a flat bed glazer, a rotary machine can be used for drying matt and semi-matt papers by loading the prints so that the emulsion side faces the cloth apron instead of the glazing surface.

The prints should not be too wet when placed in the machine, or they will not be quite dry by the time they have passed through. Too much water in the print may also convert the starch in a matt surface to paste and so give the print uneven shiny areas, especially if the moisture cannot escape sufficiently quickly.

In glossy prints the water content of the paper does not have this effect because the glazed face of the print is in contact with the polished metal plate, and drying commences there. With other papers the position is reversed, and drying commences at the back of the print, hence the moisture must escape through the emulsion surface. Excessive heat of the glazing machine can cause trouble, too. Matt prints do not call for such quick drying as glazed ones and in general can be allowed about double the time. In most rotary (and also many flat bed) glazers the temperature can be adjusted accordingly.

Generally matt papers are not hardened to the same degree as glossy papers intended for hot glazing. So here a hardening fixing bath is desirable if heat drying is to be used.

When hot glazed prints leave the glazer, they may strongly curl inwards if the paper has become too dry. They should not be flattened in this condition, as this may crack the gelatine surface. After a few minutes in the air they usually absorb sufficient moisture again to make them more pliable.

Processing Colour Prints

In a colour print the three colour images in the individual layers are formed as a by-product of substantially the same process of development as with black-and-white prints. The colour paper is thus developed in the first place to a set of black silver images. The oxidation products of the developer react with special substances – so-called colour couplers – incorporated in each print layer, to form the cyan, magenta and yellow dyes. The dye image is thus generated simultaneously with the silver image and the amount of dye produced is proportional at every point to the amount of silver developed.

After development the silver image produced is bleached out, and the print fixed.

The final stages are a wash, followed usually by a hardening after-treatment and a so-called stabilising bath (which has nothing in common with the type of stabiliser discussed on page 348) to improve the light fastness and permanence of the print.

Colour papers vary much more than black-and-white materials in the characteristics of their sensitive layers, and especially in the colour couplers used to produce the dye images. Manufacturers accordingly recommend detailed processing procedures and issue kits of chemicals specially formulated for their particular make of colour paper. These kits are available in various sizes, usually matched to the capacities of professional tank processing outfits (page 363). The processing procedures are also laid down in detail, since the baths and treatment times vary for different papers.

Equally important is accurate temperature and time control of the prints in the colour developer. Processing temperatures may range from 20° to 38°C (68° to 100°F); the most usual recommended temperature is 21° to 24°C (70° or 75°F). But the indicated temperature must be maintained with a precision of + or — $\frac{1}{4}$°C or $\frac{1}{2}$°F; the exact treatment time is equally critical for reproducible results.

For the subsequent processing stages after development, manufacturers indicate a somewhat wider temperature and time tolerance (temperatures within 2° or 3°C of the development temperature). As these processes (bleaching, fixing etc.) have to go to completion, the time and temperature for them is in fact not at all critical and longer times or lower temperatures than those suggested by the makers of the colour material are permissible.

However, there are two sound reasons for keeping closely to the processing conditions laid down:

(1) In professional practice a standard processing procedure is essential for proper organisation. The obvious way of standardising is to carry out the same steps in the same way every time.

(2) Certain intermediate treatments, such as rinses and hardening baths, do affect the colour quality of the result. So these must also be standardised.

COMPACT DRUM PROCESSING

While colour enlargements can, like black-and-white ones, be processed in dishes, this is cumbersome and involves long periods of working in the dark. An efficient modern way of handling colour prints on a small scale is in a fashion reminiscent of small development tanks for single roll or miniature films: the material is loaded into a light-tight container and the solutions poured in and out in the prescribed sequence.

For charging the tank, prints slide in from one end, with the emulsion side inward, to curl around the inside wall. The maximum print size and capacity depends on the drum; large models may handle single prints up to 30 × 40 cm or 12 × 16 inches; smaller models usually take prints at least up to 20 × 25 cm or 8 × 10 inches. Generally several smaller print formats can be loaded at the same time and fixed or removable stops or guides inside the tank prevent such prints moving over each other.

The only step needing total darkness is loading the prints which is reasonably easy by touch. A light-tight lid with a pouring funnel is then fitted over the open end and the first solution poured in. This remains in a pre-chamber or other device that keeps the solution from contacting the paper surface until the tank is laid down on its side on the work

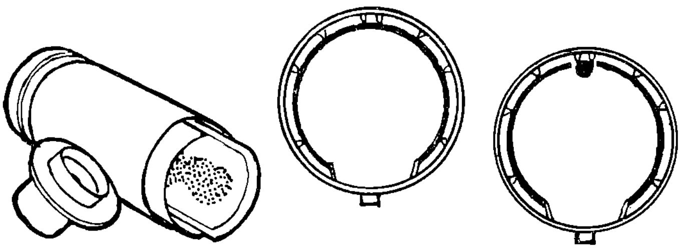
bench. The solution then flows into the main tank body and sweeps over the paper surface as the drum is rolled to and fro on the bench. This rolling action is the method of agitating the solution. With some drums mechanical or motorised roller units keep the drum rotating without rolling it on a bench.

This arrangement has the further advantage that very small solution quantities are sufficient for big prints. For instance a drum of this kind may only need 150 ml of solution for a 30 × 40 cm or 12 × 16 inch print or less than half that much for a 20 × 25 cm or 8 × 10 inch print. The solutions are used once only and discarded, which eliminates problems of replenishment and keeping track of exhaustion.

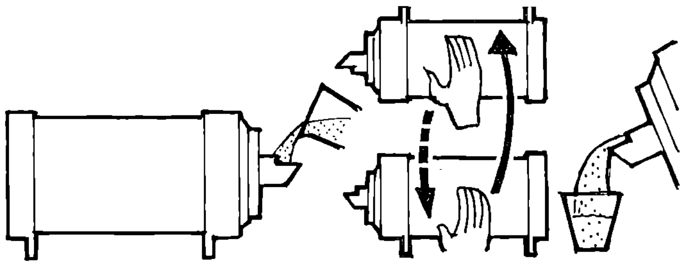
After the first processing step (e.g. colour development) inverting the drum drains the solution (which is poured away) and the next bath – rinse or stop bath etc. – can be poured in. At the end of the processing sequence the prints are removed for washing in a simple dish arrangement or high speed washer. As nearly all present day colour papers are plastic or resin coated, washing times can (and should) be short – see also page 350.

As temperature control is critical in colour processing, specially during the development step, more elaborate drums of this kind include a tempering unit that holds solution bottles and measures in a thermostatically controlled water bath. The easiest way of bringing the drum to the correct working temperature is to stand it in a similar water bath of controlled temperature, the material of the drum retains heat long enough to keep the temperature constant at least during the critical first development step.

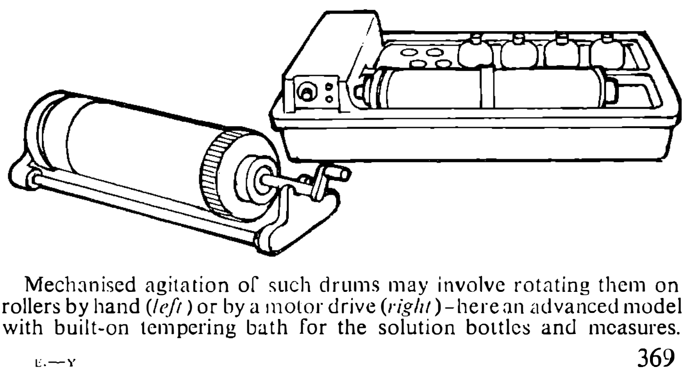
Related to this idea on a more professional scale is the tube processor which again takes prints rolled up inside a hollow tube. The tube ends are here slightly constricted and the tubes rest on motor driven rollers in a processing unit which also includes hoses or pipes leading into the horizontal print tubes. Solutions are introduced into the processing tubes holding the prints through the pipelines while the tubes rotate on their roller drives. At the end of each processing step the whole tube assembly is tilted up so that the solutions run out of the open tube ends. The next solution – or water for a rinse – is then introduced, carrying



Drum processors for paper take prints rolled up inside a hollow drum with light-tight lid (*left*). Guides hold the prints against the walls; additional guides or retainers may be fitted for multiple charging with smaller prints (*right*).



The procedure for each processing step involves pouring in the solution (*left*), rolling the drum to and fro on a table during the processing time (*centre*) and pouring out the liquid again (*right*).



Mechanised agitation of such drums may involve rotating them on rollers by hand (*left*) or by a motor drive (*right*) - here an advanced model with built-on tempering bath for the solution bottles and measures.

on until and through the final rinse. These tube processors offer the same economy of once-only solution use but automate the sequence rather more. The cabinet housing the motor and roller drive and the tubes can be closed light-tight and also kept at the required processing temperature.

For handling large quantities of colour prints in professional set-ups, one way is to process the prints in tanks similar in principle to sheet film processing installations.

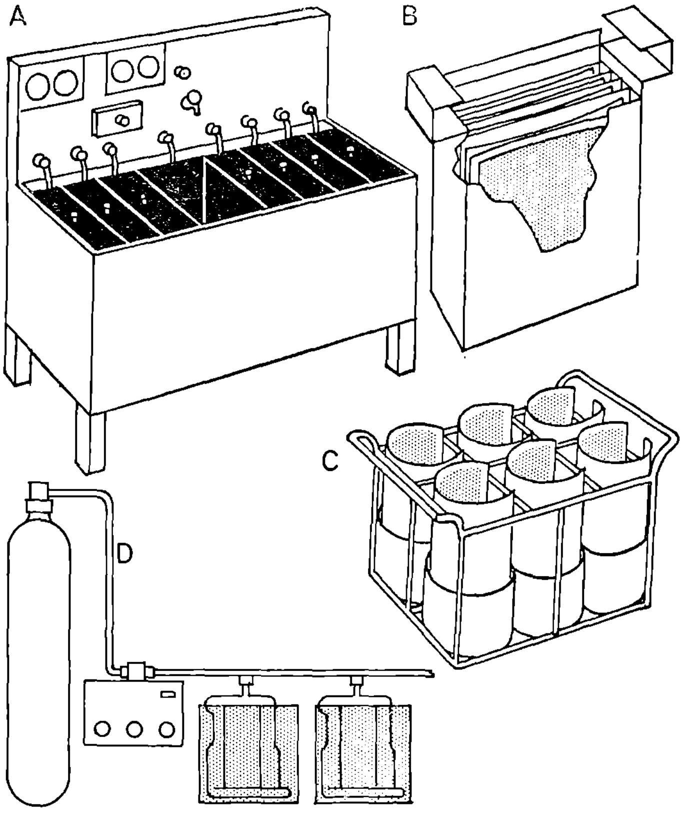
This method of working is based on accurate evaluation and grading of colour negatives before printing so that the majority of prints are correct in density and colour balance at the first attempt.

This contrasts with the amateur way of making trial prints and exposing final enlargements with the corrections in exposure and – in the case of colour – in colour balance afterwards. Such a procedure is valid for casual black-and-white enlarging, since a print can be inspected within a couple of minutes or less of exposure. Colour prints do not however show their final effect before part of the much longer processing sequence is complete; hence efficient working with a reasonable printing output calls for the separation of the exposure and processing stages of colour papers.

Processing tank sets consist of four or more solution tanks and two or more washing tanks. These take the prints either rolled up in multiple racks or flat in processing baskets in which the prints are inserted in pairs (back to back) between perforated divisions. The racks or baskets are lifted as a whole from one tank to the next for the different processing stages. To ensure accurate temperature control the individual tanks generally stand in a trough or sink filled with water and kept at the required temperature by thermostatically controlled heating (and sometimes cooling) units.

Tank sets of this type are available in various sizes, the biggest taking prints up to 40 × 50 cm or 16 × 20 inches. The whole installation then becomes bulky and requires its own water supply and drainage. They are thus usually permanently installed on the floor of the processing laboratory. Smaller tank units may, with their water bath, be accommodated on a suitable bench.

COLOUR PRINT PROCESSING TANKS



The usual professional tank set consists of a series of deep tanks – one for each processing stage including the rinsing stages – arranged inside a sink which acts as a temperature controlled water bath (A). The prints are loaded flat back to back in baskets (B), which are transferred from one tank to the next as the processing proceeds. Alternatively prints may be rolled in suitable racks (C). Nitrogen burst equipment (D) provides the necessary solution agitation. This consists of a compressed nitrogen gas cylinder, a gas distributor to feed the nitrogen at the appropriate pressure to the gas burst units in each tank, and an automatic timer to release the bursts at appropriate intervals.

An outfit with 4–5 litre tanks may process 6–8 prints 20 × 25 cm or 8 × 10 inches at a time; usually around 30 prints can be handled in a batch in a 5-litre tank set.

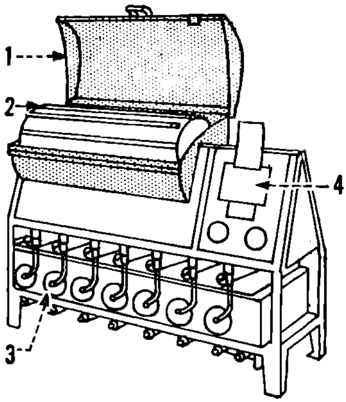
Agitation of the solutions may in simpler units be carried out by periodically lifting the processing racks or baskets out of the solutions. More elaborate units use nitrogen burst agitation. Here bursts of nitrogen gas are released from a gas distributor in the bottom of the solution tanks; the turbulence created thereby stirs up the solutions for efficient agitation. Gas burst agitation requires a supply of the gas in cylinders, a control valve which feeds the distributors in the tanks and a timing relay which automatically releases a gas burst at pre-set intervals.

PROFESSIONAL DRUM AND ROLLER PROCESSORS

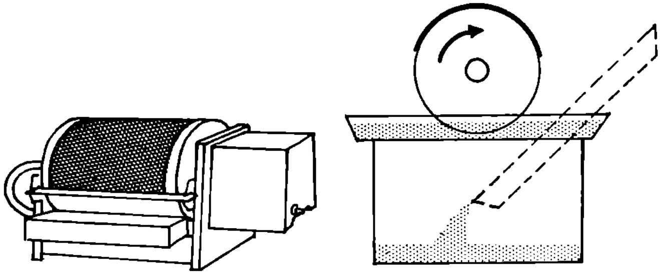
Large scale drum processors follow the principle of compact drums where the prints are kept in one spot and solutions changed in the container. This is more useful for very big prints, because the solution quantities required for deep tanks would then become enormous. Usually the prints are clipped to the outside of a drum or rotary holder which dips into a comparatively shallow tray. Again this requires far less solution than would be necessary for a tank of appropriate size to take a corresponding print format. The drum and its tray may be enclosed in a light-tight container, so that processing can take place in ordinary light once the drum has been charged. Solutions are poured or pumped into and out of the tray at the appropriate intervals. The largest units of this kind can take print sizes up to 1·2 × 2·4 metres or 4 × 8 feet.

Drum units of this kind also lend themselves to extensive processing automation. Thus the individual solutions may be pumped in succession into the tray from suitable storage containers, and the pumps set going by relays governed by a programmer. The programme itself consists of the information concerning the time intervals between the various emptying and filling steps. This programme may be recorded on perforated paper tape, on embossed plastic panels or by similar means. Once the programme is fed into the machine, the latter runs the complete processing sequence on its own.

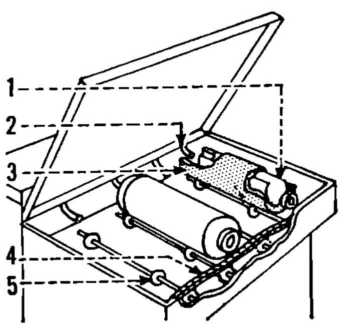
Automatic processing systems of this kind also exist for specially designed single tanks which take conventional print



Drum processors for giant colour prints carry the latter attached to a rotating drum which dips part way into the processing bath in a light-tight housing. The different baths are pumped into and out of the processing chamber from storage containers according to a pre-set programme. 1, cover of processing chamber; 2, drum; 3, solution containers and pump connections; 4, programmer.



Another type of drum processor keeps the print in sliding contact with the top of a drum which dips into a solution tray and carries the solution round to the print surface. The drum is heated to 38°C and warms the solutions to this temperature as they reach the print surface. After each processing stage the tray is emptied into a container underneath and new solution poured in.



A tube processor keeps the prints rolled up inside open ended tubes filled with a small amount of processing solution. The tubes are kept rotating so that the whole print surface is constantly swilled over by the liquid. 1, print; 2, solution (or water) inflow; 3, print tube; 4, driving chain; 5, driving roller to keep the tube rotating.

baskets. Here again solutions are pumped into and out of the tank in sequence according to the prescribed programme.

RAPID COLOUR PROCESSING

Another form of drum processer greatly reduces the treatment time of the colour paper, and does so by a combination of special chemicals and high processing temperatures (38°C or 100°F). It is suitable only for specific combinations of colour paper and chemical sets. Colour papers for this – and indeed any other – high temperature procedure are often resin coated.

A drum again rotates while dipping into a shallow tray. The drum surface is textured to pick up a film of solution from the tray and carry it round to the top of the drum. The paper to be processed is placed on the upper part of the drum and held there in sliding contact with the drum. The latter thus carries the processing solution to the print surface, but does not take the print round with it.

The inside of the drum is filled with warm water at the recommended temperature. The larger units have a recirculating system which keeps the water temperature constant. As the drum rotates, the thin solution film carried with it is warmed up to the drum temperature before it reaches the print surface. No other temperature control is therefore necessary.

At the end of each processing step the tray below the drum is emptied into a vessel underneath, and the next solution poured in. Since a 40 × 50 cm or 16 × 20 inch print requires less than 250 c.cm. of each solution, the latter are used to their full capacity. For rinses and washing the tray is repeatedly filled with plain water. The complete processing time for a colour print, excluding drying, is no more than 7½–8 minutes.

Units of this type are made for prints up to 40 × 50 cm or 16 × 20 inches respectively; they are compact enough to be accommodated in a quite a small professional darkroom. Special giant units take print sizes up to 75 × 100 cm or 30 × 40 inches.

With high temperature processing it also becomes possible to mechanise colour print development with roller processors similar in principle to black-and-white roller machines (page 327). The prints are fed into the machine,

and roller systems transport them in turn through a developer, bleach-fix solution and a final rinse, emerging half dry at the other end. The total run-through time is around 6 minutes with a processing temperature of 40°C or 104°F. This period is about the longest that can be handled reliably in not too bulky a machine, otherwise accurate speed control and even transport become difficult.

Roller processors for colour prints are necessarily more complex (and expensive) than black-and-white models since they must have provision not only for accurate temperature control and a supply of washing water but also for automatic solution replenishment. Such roller processors are however likely to replace tank and even medium sized drum processors in the professional field. At present machines of this kind can handle print sizes up to 50 × 60 cm or 20 × 24 inches. In terms of throughput capacity this means that some 40 or 50 prints 18 × 24 cm or up to 8 × 10 inches in an hour. This can conveniently keep step with the output of an operator making enlargements with semi-automatic or more or less automatic colour enlargers.

Similar roller processors may arrive in the amateur field as fast short-process chemical systems become more widespread (page 380).

SEQUENCE CONTROL

As tank processing deals with colour prints in batches, the output of a processing installation is limited by the size of the batch it will take and the time the batch requires to pass through it. It is however possible to increase the output capacity by running several batches through in such a way that a second batch can be charged before the first one has completed the sequence. This requires a certain amount of planning, so that the different steps of the first batch – especially the manipulations of transferring prints from one solution to another – do not interfere with the next batch.

To establish such a multiple processing sequence, first write down the actual processing steps and their duration, as well as the actual periods during which the batch needs manipulation. A similar sequence for a second batch can then be interlaced with the first, ensuring that the manipulative periods of this second batch fall into the clear periods of the first.

Once such an interlaced sequence is established, it is best practised with a "dummy run", both to check that the time allotted to the handling stages is adequate and that the two sequences do not interfere with each other.

To allow for unexpected contingencies, the schedule should not be too tight.

A useful way of keeping control of such a complex sequence is to record it on tape, for instance during the dummy run. Each step is timed with the aid of the prepared sequence chart, and the actual instructions – transfer of the prints from one solution to another, rinses, draining time etc. – spoken into the microphone at the right moment.

For the processing itself we then only have to start the tape recorder simultaneously with the loading of the first batch of prints into the tank system. Then simply follow the instructions as they come out of the tape recorder while the tape is running. The tape speed must be reasonably accurately controlled; as we are only concerned with spoken instructions, a recording and playback speed of $1\frac{7}{8}$ inches per second is adequate. This gives a run of about one hour with a 600 foot tape reel. A compact cassette recorder is even more convenient and more compact (especially if battery powered). The programme should however be recorded on a cassette that can run long enough without turning over – generally one side of a 90-minute compact cassette. Listening to audible instructions in this way is less distracting than keeping track of a chart and a timer in the dimly lit darkroom.

If several makes of colour paper are processed, a separate tape can be prepared for each process for use whenever required.

Tape programming units also exist for perforated paper tape. Here the duration of the processing steps is measured out in terms of length of tape which is perforated at the appropriate points. In the tape unit an audible signal (bell, buzzer etc.) sounds whenever a tape perforation moves past the scanning head to indicate that the batch in the processing sequence requires attention for the next step. Alternatively, such units can use a strip of ordinary 35 mm film (e.g. a waste film). This advances at a uniform speed through the programming unit; the required signal points are punched into the centre of the film at appropriate intervals.

UNIVERSAL COLOUR PROCESSING FORMULAE

The processing kits issued by makers of colour papers are matched to the characteristics of specific materials. The use of colour papers of different makes in the same printing department necessitates having either separate tank sets for simultaneous processing of different papers, or constant change-overs of solutions if only one tank outfit is available.

The amateur who wants to experiment with a range of colour papers, has to make up and keep an appreciable number of different solutions, which do not necessarily keep well. Various attempts have therefore been made to design universal colour processing formulae which require no more adaptation with different makes of paper than a change in the development time and possibly one or two of the other treatment times. Such universal formulae have proved reasonably successful with colour papers because the processing procedure here is appreciably simpler than for instance with reversal colour films. At the same time the results obtained are naturally different in terms of colour balance (and sometimes also in terms of contrast and maximum density) from those achieved when the paper is used with the processing chemicals specially designed for it.

Before universal formulae are taken into routine use, extensive preliminary tests are advisable to check whether a particular colour material can give acceptable results, and to establish the best treatment times and conditions. For professional practice it is usually best to stick to the maker's kits wherever possible; with universal formulae it is at least desirable to compare the results obtainable by using them with the results which the official procedure and chemicals will give.

Naturally any system of colour grading and determining colour exposures – whether by simple or more automatic methods – must be related to the exact processing procedure which will be used.

Manufacturers of colour papers – especially of lesser known or less widespread makes – often make their processing compatible with one or two leading brands. In view of market realities these tend to be the Kodak and Agfa positive colour paper systems – makers of other materials have better prospects of selling their products to professional

photographers and laboratories equipped for Kodak and/or Agfa colour print processing. Independent makes of colour processing kits are usually also compatible with one of these leading paper groups.

Developers. The following universal colour developers have been formulated to deal with all types of colour paper. Average recommended development time is 4–6 minutes at 68°F (20°C).

27 – UNIVERSAL COLOUR PRINT DEVELOPER (Dr. H. GORDON)

Hydroxyethyl-p-phenylene diamine sulphate	80 grains	4·5 grams
Potassium carbonate	3 ounces	75 grams
Potassium bromide	44 grains	2·5 grams
Sodium sulphite, anh.	35 grains	2 grams
Ethylene diamine tetra-acetic acid	27 grains	1·5 grams
Tripotassium phosphate	175 grains	10 grams
Hydroxylamine hydrochloride	35 grains	2 grams
Water to	40 ounces	1000 ml

28 – UNIVERSAL COLOUR PRINT DEVELOPER (G. THEILGAARD)

DIEPPP*	44 grains	2·5 grams
Sodium sulphite, anh.	35 grains	2 grams
Sodium carbonate, anh.	$1\frac{1}{2}$ ounces	40 grams
Potassium bromide, 10% solution	95 minims	5 ml
Hydroxylamine hydrochloride	18 grains	1 gram
Water to	40 ounces	1000 ml

* Diethyl paraphenylene diamine bisulphite (Genochrome, Activol No. 1).

In general, only a short rinse is necessary before the next stage (the stop bath). If the manufacturer recommends a longer wash, this should be carried out.

Stop Bath. If universal formulae are used, a combined stop/fix solution is preferable to a stop bath, as it reduces more effectively the danger of colour stains.

29 – STOP-FIX BATH FOR COLOUR PRINTS (G. THEILGAARD)

Sodium thiosulphate, cryst.	$9\frac{3}{4}$ ounces	240 grams
Sodium sulphite, anh.	265 grains	15 grams
Glacial acetic acid	300 minims	17 ml
Boric acid	132 grains	7·5 grams
Potassium alum	265 grains	15 grams
Water to	40 ounces	1000 ml

Average time of treatment is 5 minutes at 68°F (20°C), followed by a wash of 5 minutes.

Bleach-Fix. Prints can either be bleached in separate solutions of potassium ferricyanide and hypo, or in a combined bleach fix bath as given in formula No. 30. This combined bath shows less tendency to stain, and is of much more universal application. The bleach-fix bath is still necessary even when a stop-fix bath has been used.

30 – BLEACH-FIX BATH (Dr. H. GORDON)

Iron sequestrene (ferric salt of ethylene diamine tetra acetic acid)	$2\frac{1}{2}$ ounces	60 grams
Sodium carbonate, anh.	88 grains	5 grams
Potassium bromide	$1\frac{1}{4}$ ounces	30 grams
Sodium thiosulphate, cryst.	$9\frac{1}{4}$ ounces	230 grams
(or anhydrous)	6 ounces	150 grams
Sodium citrate	$1\frac{1}{4}$ ounces	30 grams
Potassium thiocyanate	175 grains	10 grams
Optical bleach (e.g. Tinopal BV)	60 grains	3·5 grams
Water to	40 ounces	1000 ml

The above quantity is sufficient for about 30–35 prints 20 × 25 cm. The bleach-fix bath takes about 10 minutes to act at 68°F (20°C). If the bleaching action slows up noticeably, the bath is getting near its exhaustion point.

The pH of the solution should be about 6·4 and is adjusted by adding ethylene diamine tetra acetic acid.

The iron sequestrene in the above formula can if necessary be substituted by the following combination:

Ferric chloride, cryst.	$1\frac{2}{5}$ ounces	35 grams
Ethylene diamine tetra-acetic acid	$1\frac{3}{5}$ ounces	40 grams
Sodium carbonate, anh.	$1\frac{3}{5}$ ounces	40 grams

The bleach-fix bath is followed by a wash of about 10 minutes. Alternatively, a separate hardener and stabiliser bath can be used, incorporating the optical bleach.

31 – HARDENER-STABILISER

Formalin, 40% solution	390 minims	20 ml
Optical bleach (Tinopal BV)	52 grains	3 grams
Water to	40 ounces	1000 ml

The treatment time is about 5 minutes, and the prints are dried without further washing.

TWO-BATH SHORT PROCESSES

Recent formulations of universal colour print processing kits reduce the treatment times still further, especially at higher temperatures. Typically such kits consist of a colour developer and a bleach-fixing bath that neutralises the developer and is comparatively unaffected by the carried-over developer chemicals. The procedure then consists only of colour development and bleach-fix (without any intermediate rinse or stop bath) in a compact drum, followed by washing and drying outside. At normal temperatures – i.e. 20°C or 68°F – the two steps take 5 to 6 minutes and 3 to 4 minutes respectively; at 40°C (104°F) each step can take as little as 1 minute. This shortened time is more suitable for dish processing or a roller processor – a simpler black-and-white version rather than the more elaborate colour units.

Such rapid two-step systems are again produced in alternative versions for Kodak and Agfa papers respectively (and for materials compatible with them).

The washing stage after bleach-fixing usually takes about 5 to 7 minutes, depending on temperature. Washing at around 25°C (77°F) is more convenient even after processing at a higher temperature.

DRYING AND JUDGING COLOUR PRINTS

As most present day colour print materials are plastic or resin-coated, the same drying procedure applies as for plastic-coated black-and-white prints (page 358). Colour prints may curl slightly more when dried by heat than black-and-white prints because of the three emulsion layers instead of one. But the prints usually flatten on their own once they are cooled.

Some colour paper manufacturers recommend maximum safe drying temperatures; print driers should then be adjusted accordingly where provided with appropriate controls.

Colour prints on some types of paper do not acquire the final appearance of the image, especially in terms of brilliance, until they are fully dry. This is because the colour couplers are dispersed in resin globules which have the same

refractive index as dry gelatine, but not as wet gelatine. The wet print therefore appears somewhat opalescent.

Since the dye image is formed at the same time as a metallic silver image, the colour balance of a print cannot be assessed until at least after the bleach-fixing stage. Where test prints have to be judged during processing, the subsequent stages (washing and hardening etc.) can be omitted.

Prints should be judged by an illuminant corresponding as nearly as possible to daylight quality, and not by normal tungsten lighting, even if this is the regular "white" light in a darkroom. Suitable light sources are daylight fluorescent lamps or blue tinted tungsten lamps. The latter may require some filtration (for example by a very pale yellow filter) to produce a reasonably correct daylight effect.

PROCESSING REVERSAL COLOUR PAPERS

The general principles of handling reversal papers are much the same as for positive papers, but the processing procedure is rather longer. The exact steps depend on the make of paper, and the processing kits and detailed recommendations of the manufacturer should be followed in each case. There are no "universal" formulae for reversal print processing.

A typical processing sequence consists of:

1. First development. This produces a black negative image in all three layers. It may take from 7–15 minutes.
2. Stop bath. This stops the action of the first developer. Treatment time about 2–3 minutes.
3. Washing for 5–20 minutes, according to the material.
4. Re-exposure. The print is exposed to white light to fog thoroughly all remaining silver salts in the emulsion; these are subsequently developed in a colour developer to form a silver and a dye image.
5. Colour development. This may take 8 to 15 minutes.
6. Stop bath. This arrests the action of the colour developer and may be combined with the hardening bath. Time of treatment may be from 1–5 minutes.
7. Bleaching. This converts all the silver – i.e. the first negative image and the second positive image – into silver halide for subsequent removal in the fixer. With reversal materials bleaching and fixing are usually separate.
8. Fixing. Both bleaching and fixing take 5–8 minutes.

9. Stabilisation. This is recommended with some materials and has the same function as the final hardening bath with optical bleach for positive colour prints.

Additional rinsing and washing stages are usually introduced between steps (6) and (7), (7) and (8), and (8) and (9). The recommended times vary fairly widely.

DYE BLEACH PROCESSES

In most positive and reversal colour papers as discussed above, the dye image is built up in the emulsion layers together with the silver image. By contrast, dye bleach systems start with pre-dyed emulsion layers – yellow dye in the blue sensitive layer, magenta in the green sensitive and cyan in the blue sensitive one. Exposure and processing produces appropriate silver images; these are then bleached and the dye in the image areas bleached at the same time.

Apart from the different chemistry of the sensitive material and its processing, this system yields positives from positive transparencies by straightforward processing.

When printing from a transparency, the dye bleach processing sequence typically involves a first development to form a negative silver image in each of the three sensitised layers. This is followed (after rinsing) by a dye bleach stage which bleaches the dye present in each layer in proportion to the negative silver image formed there. This leaves a positive dye image of the complementary colour to that layer's sensitivity. Following that, the silver is removed by a silver bleach bath and a fixing stage, followed by washing and drying. Numerous intermediate rinses are also involved to avoid contamination of the processing baths by carried-over chemicals from previous baths.

Dye bleach materials can be processed by any set-up capable of handling the eight or so steps involved; as the process is mainly for professional use, tank or large drum systems are normally employed (pages 370 and 372).

The key to the colour translation is the generation of a positive complementary dye image from the negative image in each layer. For instance a yellow image area in the transparency yields silver images in the green and red sensitive layers; during processing the magenta and cyan dyes in those areas are bleached out, leaving only a yellow dye image. Other colours are built up in an analogous way.

Dye bleach materials are marketed on opaque white or on transparent plastic base for prints and for transparencies respectively from original transparencies. The chemistry of the print and transparency materials differs slightly in detail, but not in principle.

The dye bleach process also lends itself to making positive prints from colour negatives, but the processing sequence is here more involved and no such negative-positive dye bleach materials are marketed. In principle, when printing from a colour negative with a dye bleach process, a positive silver image would first be formed in each emulsion layer. This then needs reversal – by bleaching and redevelopment of the remaining silver salts to a negative silver image. The dye bleach takes place only in conjunction with the bleaching of this negative image. Obviously processing negative-positive materials by chromogenic development is simpler.

The printing and correction principles for making dye bleach positives from transparencies are the same as for printing transparencies on ordinary reversal colour papers (page 322).

The most significant advantage – apart from simpler reversal processing – of the silver dye bleach process is that the dyes employed are greatly superior in light fastness to dyes formed by colour coupling development. Hence dye bleach prints and transparencies are popular as giant enlargements for mural decoration and for giant display transparencies – which are necessarily exposed to strong light for long periods that could cause traditional colour prints and transparencies to fade.

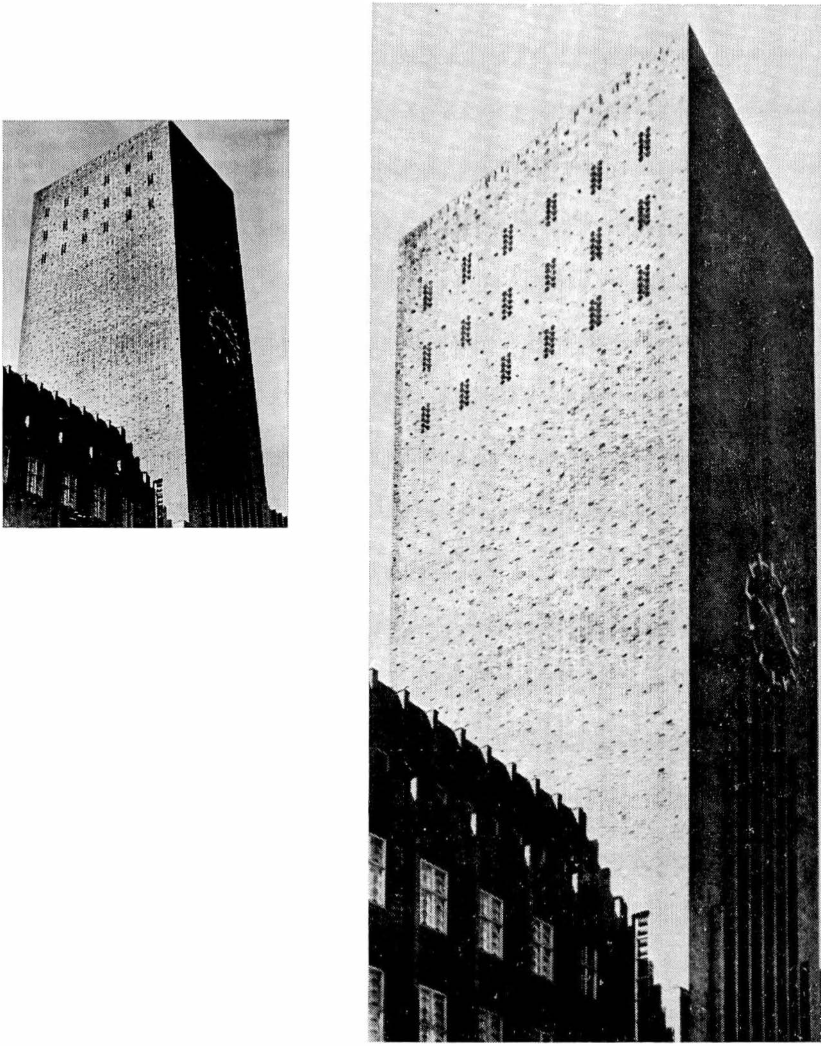
Finer Points of Enlarging

The preceding chapters have covered the techniques of obtaining the best straightforward black-and-white or colour print. There is a variety of refinements in technique, partly to improve prints aesthetically and partly to obtain special effects. The procedures are generally described as corrective techniques of enlarging, though the boundary between correction and falsification (in terms of "true" reproduction) is not always sharply defined. This is in itself not particularly significant, but before discussing these techniques further we must make two reservations:

(1) The aesthetics of enlarging tricks are a controversial issue. They are also a matter of taste, and this is not the place to go into the often academic arguments as to what techniques are or are not justified in a photographic representation. As far as we are concerned here, the techniques to be described are means to an end and are considered as justified by the latter. In other words, we are dealing with methods and it is up to the photographer what use he makes of them.

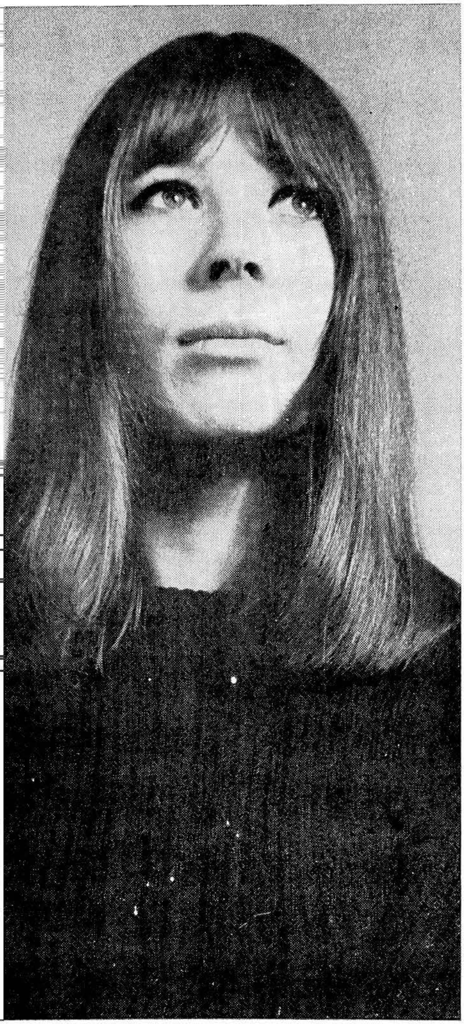
(2) Many of the techniques involve a considerable amount of experimentation to obtain the desired effect. They are thus not directly appropriate to routine procedures in a professional darkroom until the best conditions of obtaining – not once but repeatedly – the desired result have been established. In other words consistency – with unusual as much as with straightforward methods – depends on standardisation of procedure. Trial-and-error experiments are of course necessary even in professional practice, for instance where a photographer aims at a particular visual impact depending on technique (like tone separation or posterisation). But these trials will be directed at finding the optimum conditions under which the technique chosen is to be applied, and not at finding a new technique.

With these qualifications we can now look more closely at the methods available. For clarity they may be classified as:

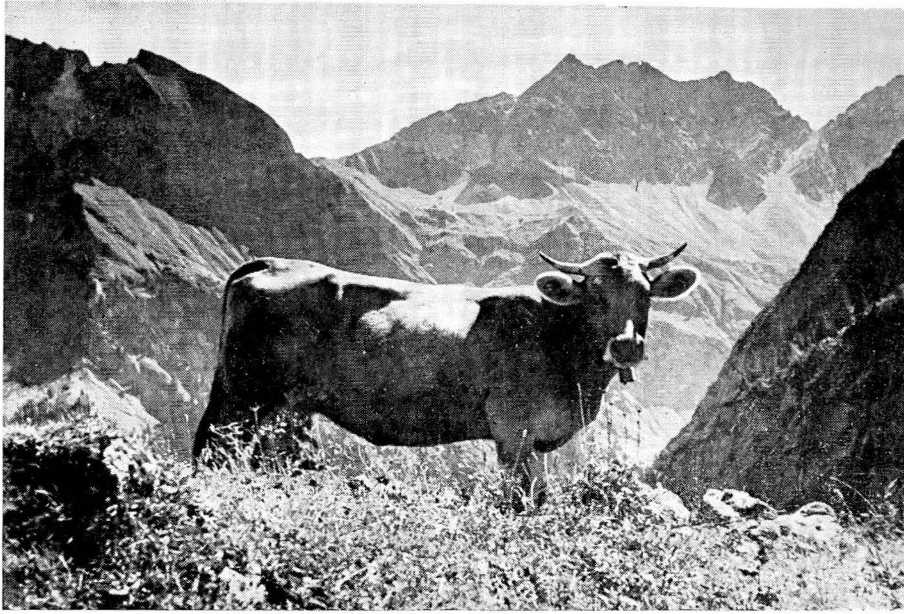


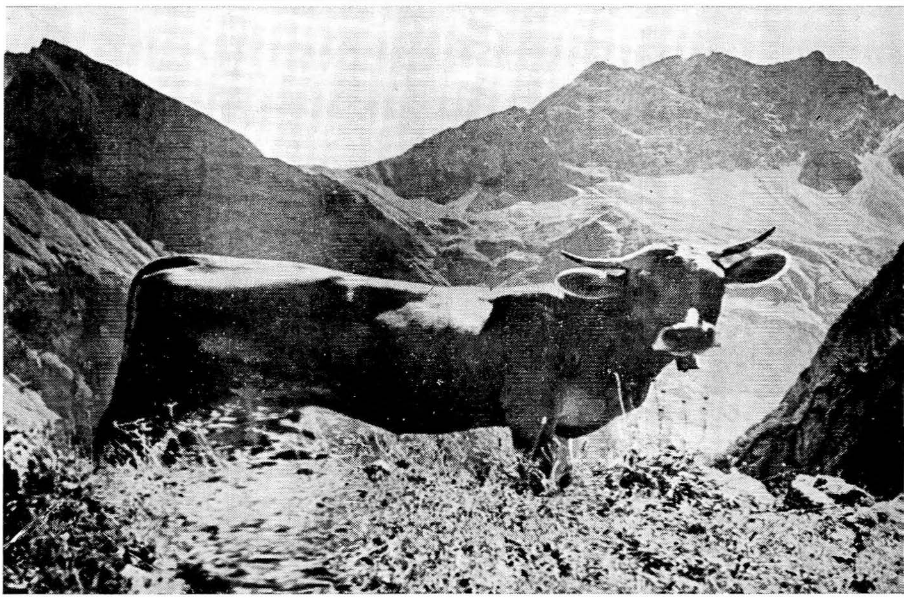
CORRECTING CONVERGING VERTICALS. In architectural and similar pictures taken with a miniature camera it may be necessary to tilt the camera in order to get the whole of a tall building into the picture. The resulting "leaning backwards" effect may be corrected to some extent during enlarging (page 401), by tilting the paper or negative, or both.

ANGLING THE PRINT. A considerably simpler way of controlling the visual effect of a picture lies in shifting the paper on the enlarger baseboard. Here a slight turn of the paper holder has made the snow-covered slope (*above*) appear appreciably steeper (*opposite*). This treatment is also suitable to improve the impact of portraits, but needs a watchful eye on obvious verticals (lamp posts, buildings etc.) in landscapes.



DELIBERATE DISTORTION. Tilting the paper holder (and possibly the negative) during enlarging can also introduce deliberate distortion. This may be useful to modify proportions—for example to turn the somewhat round face of the girl *above* into a slimmer version—or for humorous effects (*opposite*). For the stretched cow the paper was curved on the baseboard, the sides being bent up (see also page 383). Photos: *Nicholas Holt*.





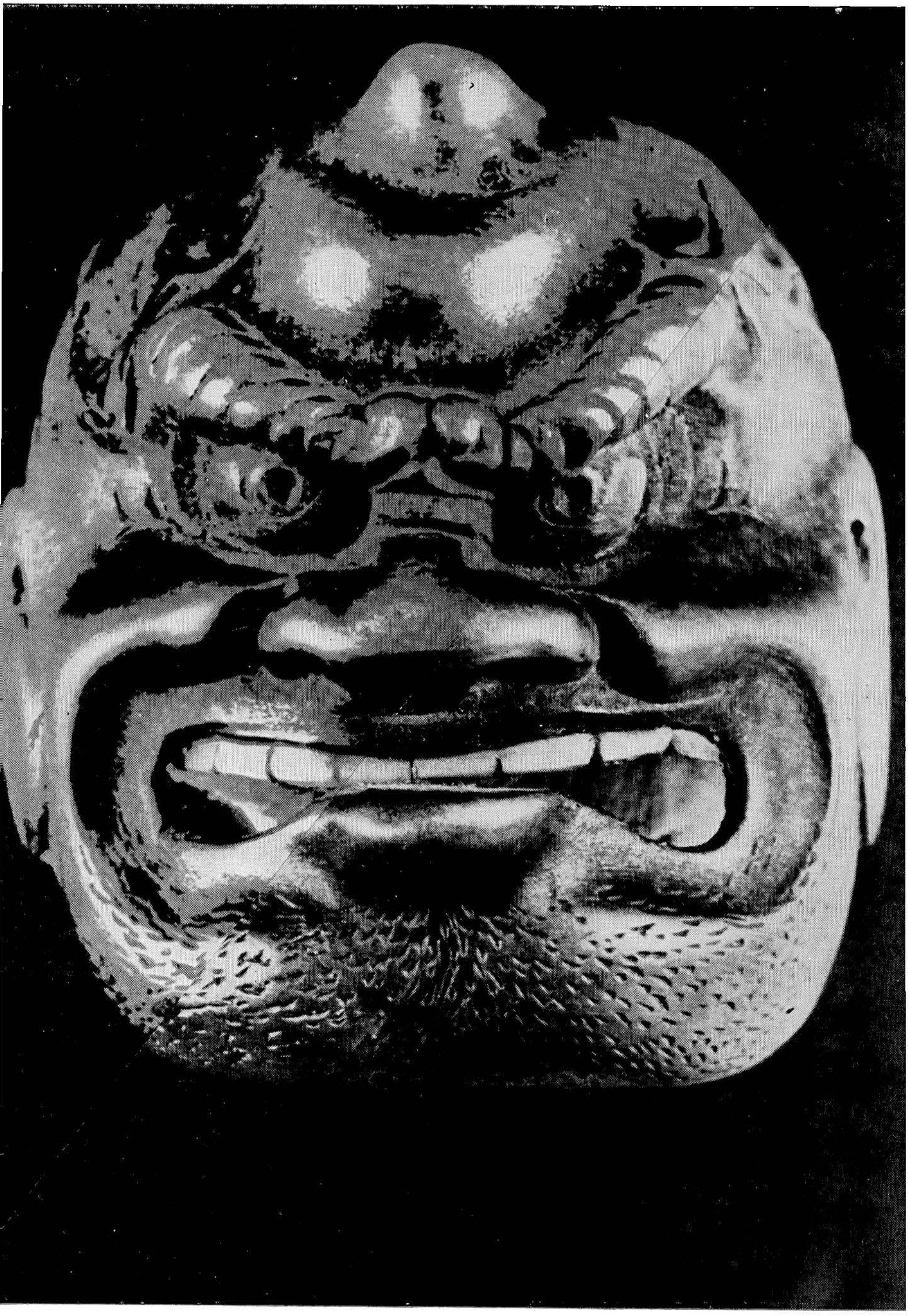
On Pages 390 and 391: SOFT FOCUS. With some subjects (e.g certain portraits) extreme image sharpness may make the picture too harsh. A diffusing attachment in front of the enlarger lens there softens both detail and contrast for a more pleasant result (page 391). This softening should not involve loss of resolution but only of acutance, because the edge contrast of the image detail is reduced (see also page 46). Photos: *B. Patterson.*

TRICKS WITH THE TONE RANGE. Some pictorial effects depend on abandoning the natural tone range of the image in favour of various types of compression. Some of these tone modifications can only take place during enlarging.

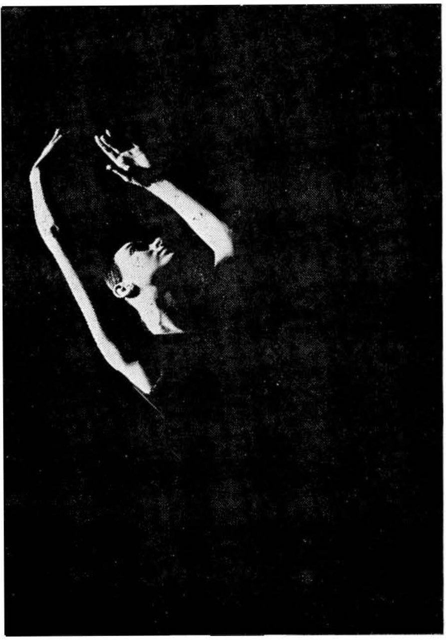
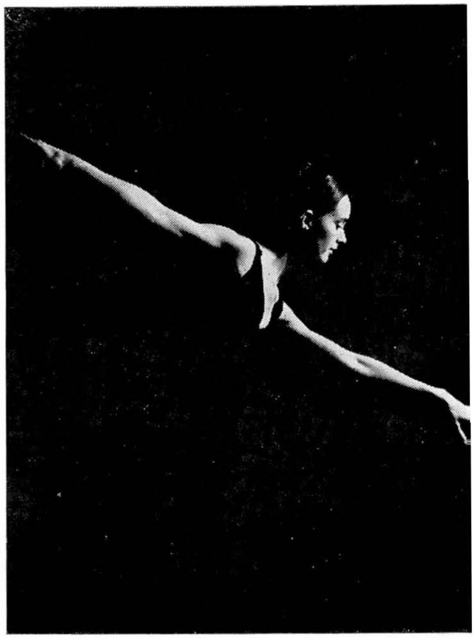
High key pictures (*opposite*) need a subject of low contrast consisting predominantly of light tones. The enlargement is made on a soft paper with the exposure kept short (page 416). Photo: *A. Kremnitz.*

High-contrast abstraction (*above*) involves duplicating the negative in one or more stages on high-contrast material until all mid-tones are lost and only black and white remain (page 474). Photo: *Eric Wendelboe.*

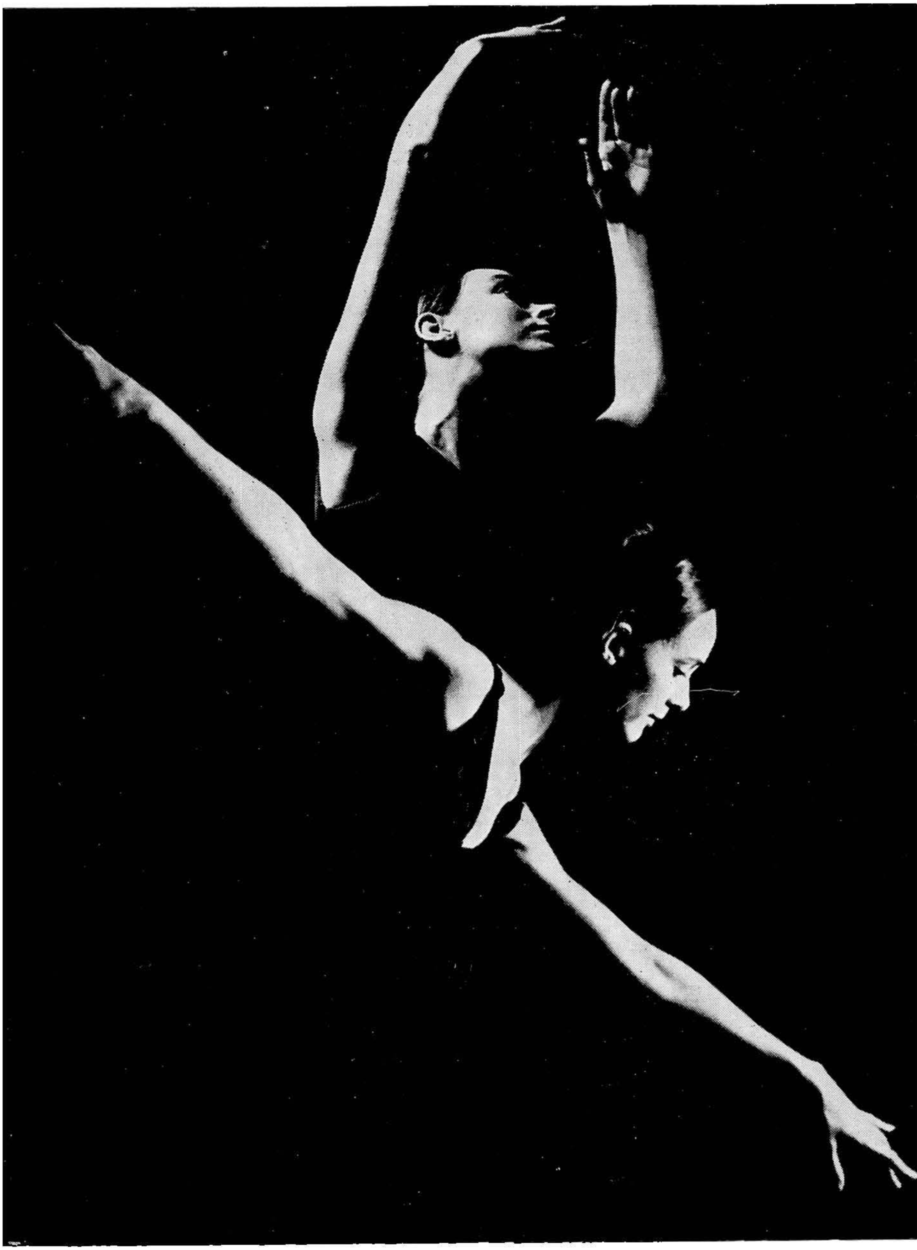
Posterization (page 394) reduces the continuous tone range to a few distinct tones (white, grey and black only in the upper left half of the picture) by a combination of duplicate negatives of different tone characteristics (see page 485). Photos: *O. Croy.*

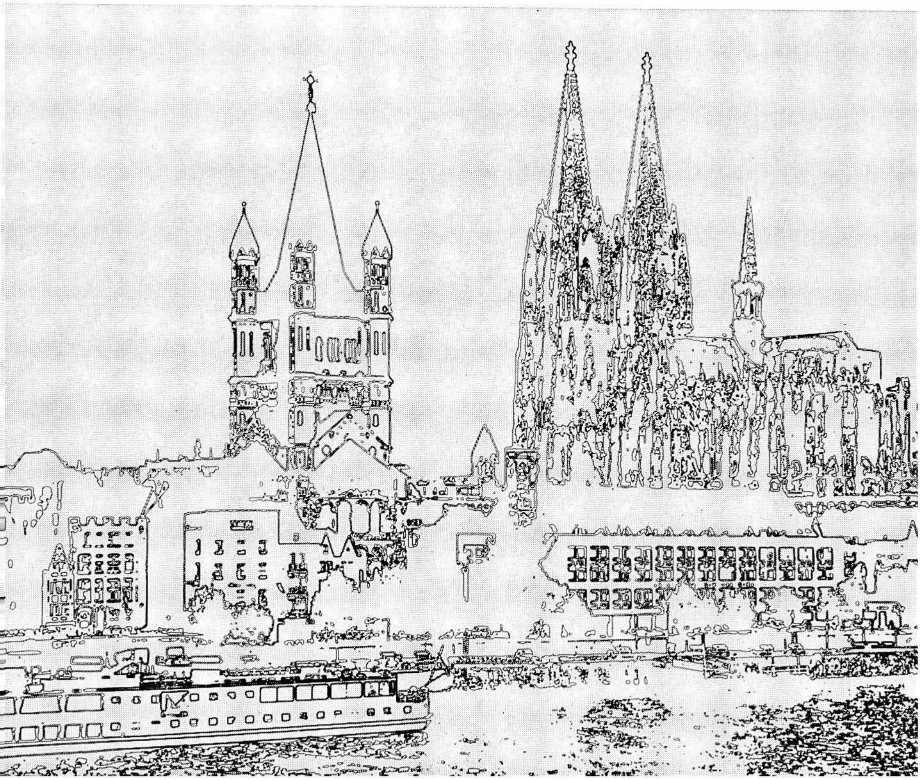


PRINTING IN CLOUDS. Portions of two different negatives can be printed in succession on the same paper—for example to add clouds to a cloudless sky (see page 482). The cloud negative should match the landscape both physically (direction of light etc.) and pictorially.

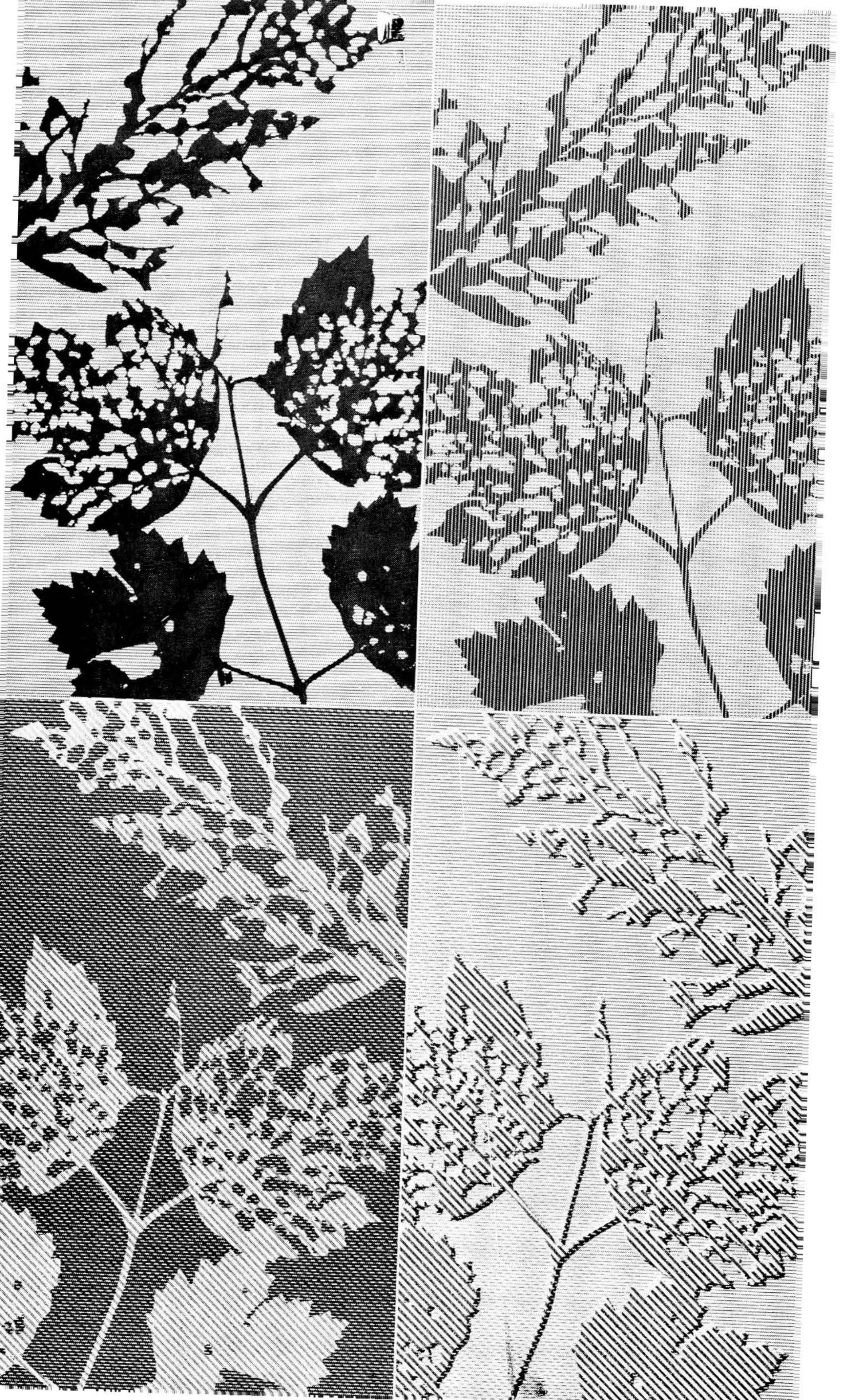
COMBINATION PRINTING. Where the negatives consist of large transparent areas, they can be combined in the negative carrier of the enlarger (see page 481). The two images must however match in scale, sometimes it may be necessary to duplicate one of them for this purpose. During the single exposure each image prints in the blank area of the other. Photos: *R. Landau.*





PSEUDO-SOLARISATION. If a print is briefly exposed to white light during development, the normal image (*opposite*, *top left*) suffers partial reversal (*opposite*, *top right*), with details outlined by a characteristic white or black contour (see also page 439). The effect depends on appropriate matching of the fogging exposure and the development time before it and after. Solarization effects look best if made on a positive film from the negative (the *top right* section *opposite* is an enlargement from such a solarized positive) or on a duplicate negative. They can be combined with posterization and other effects (for example *above*: see also page 495). Equidensity films give special solarisation effects with simple processing by turning a half-tone image into an outline picture (*opposite bottom*, see also page 490). This is a print from a second-order equidensity negative. Photos: *O. Croy* (*opposite top*), *Agfa-Gevaert* (*opposite*, *bottom*) and *Leopold Fischer* (*above*).

On page 400: SCREEN COMBINATIONS. Texture or regular mechanical screens (see also page 435) can be superimposed on the print or combined with the negative in the carrier during the exposure (*top left*). On making a duplicate negative with a second screen, the latter produces different combination patterns in the dark and light areas (*top right*). Such negatives and positives can be combined for various effects (*bottom*: see also page 493). Photos: *O. Croy*.



(a) Controlling image proportions (correction and creation of distortion);
(b) Control of image tone and contrast;
(c) Control of image sharpness and texture.

We shall deal in a later chapter with special techniques exclusively concerned with processing.

DISTORTION AND ITS CORRECTION

If the camera is tilted upwards while photographing an architectural structure, buildings appear to "fall over backwards" in the picture. This is because the vertical edges of the building, which should be parallel on the negative, are actually inclined at an angle to each other.

This is of course the normal result of perspective rendering in an optically projected image. It is thus not really distortion. We get the same effect if we point the camera downwards when looking at buildings from above, and indeed the convergence of the sides of a road with the camera pointed horizontally is the result of the same kind of perspective rendering. We have however a mental image that buildings should appear upright and a picture in which they do not is often disturbing. (This does not apply to really dramatic tilts where the camera is looking directly up at a tall structure, but to the slight tilt made necessary to get in the top of a building in a normal view – if the camera has no adjustments for perspective control.)

Such "distortion" can to some extent be corrected in the enlarger by simply tilting the paper holder until the lines which converge in the negative are parallel on the paper. There are special devices on advanced enlargers to permit convenient and rapid adjustment of the angle of tilt, but a pile of thin books to prop up one side of the masking frame or paper holder is usually perfectly satisfactory in practice. This assumes that the correction aimed at is confined to the rectification of converging perpendiculars.

Tilting the paper holder or masking frame necessarily makes part of the enlarged image unsharp, so that it is normally essential to stop down the lens until the image becomes evenly sharp again over the whole print area. In addition the exposure also will be uneven since – strictly speaking – the top of the picture is enlarged to a different scale from the bottom. Such prints therefore need extensive

shading (page 412) to get the image depth even. The small stop may mean that exposures required get very long.

More convenient is an enlarger which permits tilting of both the negative carrier and the paper holder. By adjusting the tilt of the two until the plane of the negative and of the paper holder intersect the plane of the lens panel, the image will be evenly sharp all over (page 403). By varying the relative tilts of the negative and image planes while keeping to this condition of intersection, we can also arrive at a position where the vertical lines of the image become parallel on the paper holder. This condition of intersection of the planes of the negative, lens and projected image is also known in Europe as "Scheimpflug's condition". The illumination over the image plane also becomes more even, though some shading is usually still necessary.

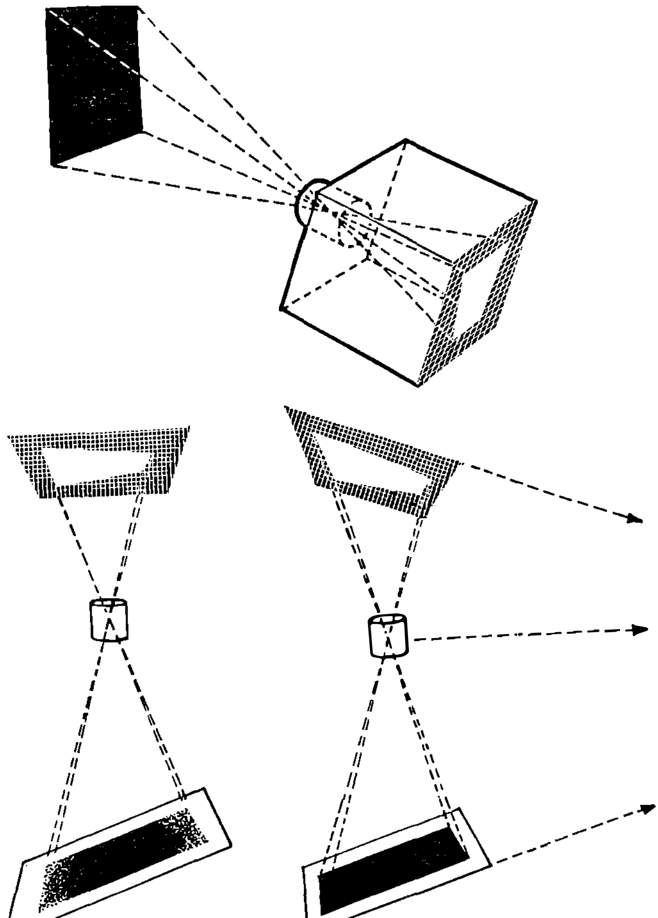
In practice tilting arrangements involving the negative can be achieved by:

(a) Tilting the negative carrier; or
(b) Tilting the lens panel, usually in conjunction with the enlarger head.

The second method has the advantage that adjustment of the lens tilt permits visual estimation on the baseboard that Scheimpflug's condition has been obtained, by simply seeing that the image is sharp all over at a large lens aperture. This type of lens adjustment further lends itself to easier distortion correction, as we shall see on page 410.

On professional enlargers (see also page 162) the degree of tilting of the baseboard, negative carrier and/or lens panel can usually be read off a scale. This also is useful for establishing exact tilts to permit accurate distortion control.

By similar methods, distortion can also be introduced into a print where it was not present in a negative. If we tilt the paper holder, dimensions in the direction of the tilt are stretched and dimensions at right angles to the direction of the tilt compressed. The compression is greatest at the highest point of the paper. The paper can even be bent inwards or outwards on the enlarger baseboard, being held in place by a couple of books or boxes. Deliberate distortion of this type is not merely useful in producing amusing caricatures, but is used in portrait and fashion studies to make a human figure or some part of it appear slimmer than it really is.



Tilting of the camera leads to distortion (*top*): the verticals of the square converge towards the top end. To get all the sides parallel we can tilt the paper during enlarging (*bottom left*); this however elongates the square into a rectangle, and the image is not uniformly sharp. By tilting both the negative and the enlarging paper in opposite directions (*right*) the image can be brought uniformly sharp all over if the planes of the negative, lens and paper meet in one point (the so-called Scheimpflug position). See also page 402.

Tilting the paper plane and/or the negative carrier in enlarging may bring converging lines back to parallelism, but at the same time usually introduces real distortion in the image proportions. The correction of converging verticals in this way leads to geometrically correct reproduction only under certain very specific conditions. Further, these conditions are different when the distortion is due to a tilt of the camera, from what they are when the camera is held level and the film plane only tilted. The former is of much greater practical interest, and only problems connected with distortion due to a bodily tilt of the camera will here be considered in detail. (If the camera has swing back and other movements, it can usually be set up in the first place to record verticals parallel on the film.)

To consider the conditions to be satisfied in correcting converging verticals and distortion, let us assume that the original object photographed is a square. If the camera points upwards at the object, the image on the film is not a square, but has a trapezoid or keystone shape (page 403). A corrected enlargement must show:

(a) The sides of the figure parallel again;
(b) The figure as a true square, and not as a rectangle which it usually tends to be; and
(c) The image sharp over its whole area.

To meet these stipulations a number of factors must be in correct relationship to each other: the focal length f of the camera lens used, the focal length F of the enlarging lens, the degree of magnification M, and the tangents of the angles of tilt $\tan n$ of the negative and $\tan p$ of the paper. For instance Scheimpflug's condition may satisfy points (a) and (c) above, but may not satisfy (b). An exact solution is only possible in certain circumstances, but there are a number of compromises.

(1) *Tilting the Paper Only.* The crudest approximate solution is to keep the negative square to the enlarging lens, and to tilt the paper plane as shown on page 403 until the lines that should be parallel are actually so. In this case the image is generally elongated in the direction of the tilt. To eliminate this elongation, the focal lengths f of the camera lens and F

of the enlarger lens and the degree of enlargement M must obey the equation:

$$M = F/(f - F) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(i)}$$

Thus if the camera lens has a focal length of 100 mm and the enlarger lens of 75 mm,

$$M = 75/(100 - 75), \text{ i.e. } \mathrm{M} = 3$$

and the enlargement must be a threefold one.

For this method of eliminating distortion the enlarger lens must thus have a shorter focus than the camera lens. Except where the taking lens is a telephoto type, this is apt to lead to trouble in getting the enlarger lens to cover the area of the negative. Further, if the same lens is used both for taking and enlarging, the distortion is reduced to a minimum by enlarging the image to the highest possible degree. There are equations giving the degree of elongation encountered, but they depend on such things as camera tilt, etc., and it is not possible to give brief tables. With this simple method the enlarging lens also must be stopped down considerably to yield reasonably sharp definition over the whole image area.

(2) *Exact Correction.* Where the negative carrier and the paper plane can be tilted, an exact solution of the problem formulated above becomes possible even when the enlarger lens has a longer focal length than the camera lens. At the correct degree of enlargement, the shape and proportions are correct, and the image uniformly sharp without stopping down the lens.

The relevant equation is:

$$M = x/\sqrt{(x^2 - 1)} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(ii)}$$

where x is F/f, i.e. the ratio of the focal length of the enlarging lens to that of the camera lens, and M is the magnification. For even definition over the whole image area the angle of tilt n of the negative carrier and p of the paper plane must be related to the magnification by the equation:

$$M = (\tan p)/(\tan n) \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(iii)}$$

and this relationship of the tilts has been assumed in working out the equation (ii) given above. At the specified magnification and relationship of the tilts of the negative and paper planes, these tilts at the same time make the converging

lines parallel and reproduce the shape of the object in its correct proportions in the print. Also the image is sharp all over, in other words we have satisfied conditions (a), (b) and (c) on page 404.

For example with a taking lens of 75 mm and an enlarger lens of 100 mm focal length, M must be 1·51. This is the required magnification of the negative in the print and also the ratio of the tangents of the angles of the paper plane and of the negative plane respectively. (This is where it is useful to have the inclinations of the enlarger baseboard and of the negative carrier calibrated in degrees; the tangents can be looked up in any set of trigonometrical tables.) Where the angles of tilt are small – below about 12°–15° – the relationship of the angles themselves rather than their tangents is a good enough approximation.

The table below gives the magnifications needed for a range of values of x, the ratio between the focal length of the enlarger and taking lenses.

XXII – MAGNIFICATIONS TO CORRECT DISTORTION

Value of x	1·05	1·1	1·15	1·2	1·25	1·3	1·35	1·4	1·45	1·5
Value of M	3·3	2·4	2·0	1·8	1·65	1·55	1·5	1·45	1·4	1·35
Value of x	1·55	1·6	1·65	1·7	1·75	1·8	1·85	1·9	1·95	2·0
Value of M	1·3	1·3	1·25	1·25	1·2	1·2	1·2	1·2	1·15	1·15

Values are calculated to the nearest 0·05.

Given the inclination of the camera, it is possible to work out the tilts of the negative and paper planes, but this is hardly a practical proposition outside certain fields of scientific photography. It is much simpler to find the necessary tilts experimentally, for instance in the following way. Start with an arbitrary tilt, for example 5° of the negative, so that the end where the converging lines are farthest apart is raised away from the enlarging lens. Suppose that the magnification demanded by the equation (ii) above is, as in the example quoted, 1½. Then the paper frame, masking frame or baseboard must be tilted in an opposite direction to the negative, through an angle of 5 × 1½, i.e. 7½°. Adjust the paper plane to this angle and examine the image to see

whether the lines are properly parallel. If they are not, increase or decrease the tilts of the negative and the paper plane in the required ratio by trial and error until a setting is obtained where the lines are parallel. The enlargement is then sharp all over, and the proportions are correct without elongation or compression of dimensions.

Where a first-class job of correcting distortion is required, the procedure to follow is to make a positive with the degree of magnification demanded by the equations given above. From this positive – made on positive film rather than paper – prepare a further negative (by contact or projection printing) and then enlarge this to the final size required in the normal way, with the negative and image planes at right angles to the lens axis. (By reversal processing of the first intermediate image on positive film, we can obtain the required negative in one step – see also page 442.) As a practical point, the focal length of the enlarging lens used at the distortion correcting stage should be the longest available. This helps to keep down the size of the intermediate negative and makes it more easy handled for the final enlargement.

When this rather elaborate, but exact, procedure is ruled out for any reason, there are still several approximate methods available. These usually involve some sacrifice in overall image sharpness, though this can be reduced by stopping down the lens.

(3) *Approximate Correction.* If it is impractical to enlarge the negative to the precise magnification stipulated in method (2) above, we can still make the converging lines parallel and reproduce the object in its correct proportions in the image if we are prepared to compensate for any lack of sharpness in the image plane by stopping down the lens far enough. The problem so posed may be solved by establishing the correct ratio between the tilts of the negative and the paper plane, according to the equation:

$$R = \frac{y^2 + 1}{y^2 - 1}, \text{ where } y = \frac{M + 1}{M} \times \frac{F}{f} \quad . \ . \ \text{(iv)}$$

where F is the focal length of the enlarger lens, f the focal length of the camera lens used and M the magnification. R is the ratio of the tilts of the paper plane to the negative plane, i.e. strictly speaking $(\tan p)/(\tan n)$, but the simple

ratio p/n is adequate where the values of p and n are smaller than about 15°.

The calculation is slightly lengthy, but straightforward. For instance if the magnification is to be 3 diameters, the camera lens has a focal length of 100 mm and the enlarging lens one of 125 mm, the expression y becomes:

$$y = \frac{3+1}{3} \times \frac{125}{100} = \frac{5}{3}$$

R then becomes:

$$\frac{(5/3)^2 + 1}{(5/3)^2 - 1} = \frac{34/9}{16/9} = 2{\cdot}125$$

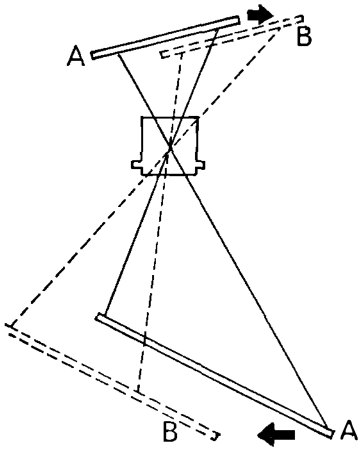
With sufficient accuracy for all but specialised architectural work the inclination of the paper plane should be twice that of the negative plane. By systematically tilting the negative through a series of angles until lines that should be parallel are parallel, as explained above, always keeping the tilt of the paper plane twice that of the negative, the proportions will be correct when all convergence of such lines has been eliminated. The lens will need stopping down to ensure sharp definition over the whole image area.

Where the same lens is used for taking and enlarging, the equation (iv) reduces to:

$$R = (2M^2 + 2M + 1)/(2M + 1) \quad . \; . \; . \quad \text{(v)}$$

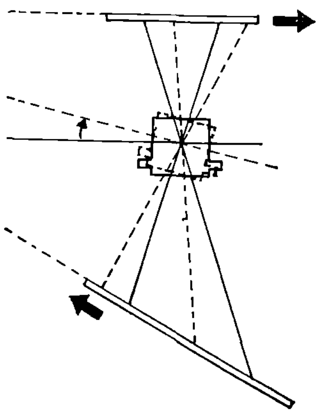
So where the focal lengths of the camera and enlarging lenses are identical and the tilts are adjusted – in the ratio R – to get the converging lines parallel, the proportions are also correct. Moreover the definition is most even and a minimum of stopping down is needed when the magnification is as high as is practicable. This conclusion is thus similar to the one arrived at with the first method where only the paper holder is tilted, in the special case of the lens of the same focal length being used on the camera and on the enlarger (page 404).

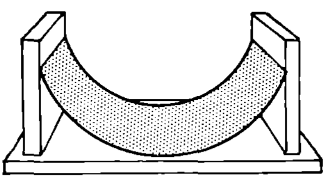
(4) *The Charles Method.* An ingenious (but approximate) method is that described by the late *David Charles.* This has the advantage of requiring no mathematical calculations. The enlarger is first adjusted to give the required magnification with the negative and paper planes both at right angles to the lens axis (i.e. without tilting). Both the negative and

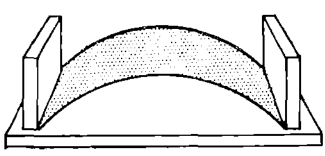


The David Charles method of distortion correction (page 408) corrects also the proportions of the image by moving the negative and the paper along horizontal planes in opposite directions, without changing their angle. The proportions of the image with negative and paper in positions A are not the same as in position B and it is possible to adjust the two until the image proportions on the paper are correct.

Instead of tilting the negative and paper it is sometimes more convenient to tilt the lens plane and paper. For uniform overall sharpness and proper correction the planes of the negative, lens and paper should again converge in one point. Also it may be necessary to move the negative and the paper holder to centre the image in the lens field (arrows).







For irregular distortions the paper may be curved on the baseboard – best achieved by locating it between a couple of books or blocks of wood. The paper surface may either be concave (*upper left*) or convex (*bottom*) – or even wavy (provided it can be kept in that position).

the paper are then tilted in opposite directions until the converging lines are parallel and the definition is even over the whole of the image area (i.e. to satisfy the Scheimpflug condition – page 402). This can be done by trial and error, alternately adjusting the negative and the paper tilt. Usually the image proportions will not however be correct.

The next step is to slide the negative carrier and the paper holder sideways without changing their tilts (as shown on page 409). This upsets the condition for exact parallelism of the lines, and the tilts have to be readjusted. When the converging lines are once more parallel, the image proportions will however have changed, the image being either more compressed or more elongated than before. (At this point the sharpness will no longer be uniform over the image plane.)

By trial-and-error lateral adjustments of the negative and paper positions and of the respective tilts a position can be found where the lines are parallel and the proportions correct. The enlarger lens is then stopped down sufficiently to ensure even sharpness over the whole of the image. The amount of stopping down required is less at high magnifications than at low ones.

This method needs an enlarger permitting the necessary lateral movement of the negative in the negative stage and the paper holder on the baseboard, plus an enlarging lens covering a sufficiently large field. This is easiest to achieve with a comparatively small negative size in an enlarger designed for bigger negative formats.

(5) *Tilting the Enlarging Lens.* Another way of providing the extra flexibility is to use an enlarger in which the lens panel can be tilted. With a normal enlarger the relative positions of negative, lens and paper holder are fixed once the degree of enlargement is settled, because the centre of the enlargement must be kept sharp to reduce stopping down of the lens within reasonable bounds. With a tilting lens and an arbitrary arrangement of the negative carrier and paper holder it is possible to obtain uniform sharpness over the image plane by tilting the lens. This changes the relative distances, *measured along the lens axis*, between the lens and the negative and the lens and the paper.

The simplest practical procedure is to start with the lens axis at right angles to the negative plane, focus the image at

the required magnification and then tilt the paper holder until the converging lines are parallel. If the image proportions are incorrect, the enlarging lens is now moved nearer to or farther away from the negative and the paper holder moved as well to keep the magnification the same (without regard to definition) and then tilted to make the required lines parallel again. The definition is now evened up over the image area by tilting the lens, and the proportions of the enlargement examined. These will have changed from what they were at the previous setting of the enlarger. By trial and error adjustments of this kind a position can be found where the proportions of the enlargement are correct, and the converging lines of the negative parallel in the projected image. The lens must in this case again cover a rather larger field than in an orthodox enlarger – i.e. it must be able to cover a bigger format than is actually being used. So choose a lens of appropriately longer focal length.

(6) *Distortion Through Camera Swings.* Finally we will consider briefly the rectification of distortion introduced when the camera is held level, but the camera back is tilted. An exact solution – satisfying the conditions (a), (b) and (c) laid down on page 403 – is only possible in this case by reducing instead of enlarging the negative. The need for reducing is not as a rule specially inconvenient, as cameras with movements such as back swings and tilts are usually models taking large negative formats. This type of rectification is suitable for architectural pictures in which exact proportions and high quality definition are of paramount importance. The reduction needed for correct reproduction is given by the equation:

$$M = 1/\sqrt{(1 + x^2)} \quad . \; . \; . \; . \; . \; . \quad \text{(vi)}$$

where x is F/f, i.e. the ratio of the focal lengths of the enlarger and camera lenses, and M the scale of reproduction which in this case is smaller than 1 for a reduction. For instance if the focal length of the camera lens is 250 mm and that of the enlarging lens 300 mm, the above equation gives $M = 0 \cdot 64$, with sufficient accuracy. So the proportions would be correct if the negative is reduced to two-thirds of its original size, with the paper holder tilted through an angle which is two-thirds of the tilt of the negative carrier.

If a reduced copy of the negative is made in the way specified, with the degree of reduction indicated by the above equation, the image will have the correct proportions and will be sharp enough over its whole area either for making a new negative or – if processed by reversal – to serve as the intermediate negative itself. The latter can then be enlarged in the usual way to give a final print of the required size. Note that there is no restriction placed on the focal length of the taking and enlarging lenses.

Approximate methods may also be applied to the correction of distortion arising in this way, such as the *Charles* method, or the use of a tilting enlarger lens.

SHADING

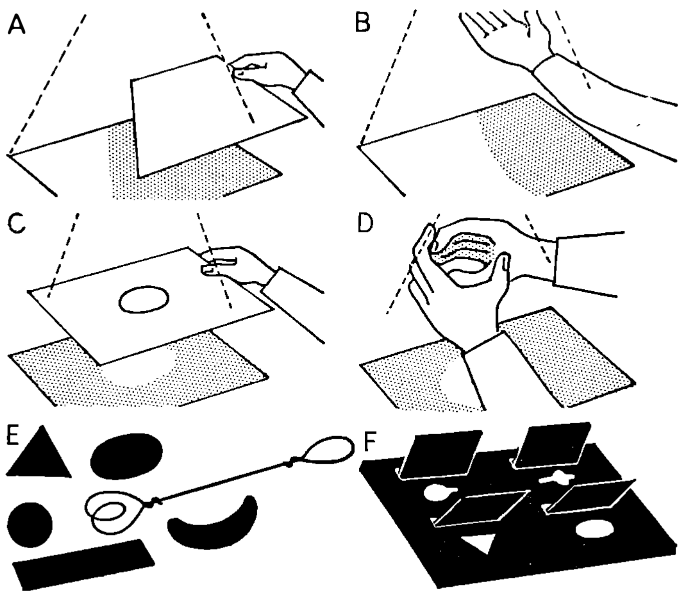
Where distortion is intended or removed, the portion of the image closest to the enlarger lens generally prints darker, since the light is there more intense. To compensate for this uneven exposure over the print we have to shade the latter during the exposure. The technique is also conveniently used on all occasions where it is necessary to vary locally the exposure given to a print. For example landscape negatives may be shaded during printing to darken the sky and show up the clouds better.

Shading, also known as dodging, in its simplest form involves placing the hand between the enlarger lens and the paper, and shaping it so that it casts a shadow which follows the outline of the portion of the image to be held back. The shaded area then prints lighter than the unshaded portions on which the principal exposure is based. The hand must be kept moving during exposure to prevent the shadow edge appearing as a hard line.

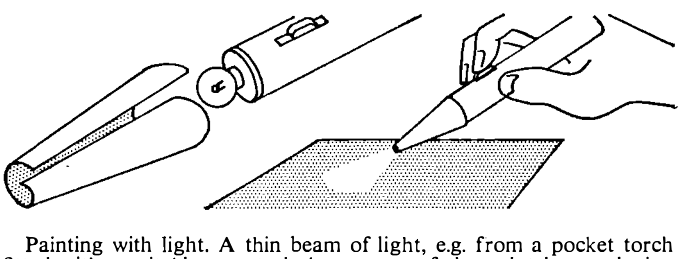
Where the hand is too large for the image area to be held back, or cannot be shaped suitably, a piece of card may be cut to the outline required and used as a substitute. A piece of red plastic foil is even better for black-and-white enlarging (except possibly with panchromatic papers) as the image can also be observed in the shaded area.

For small image portions which require shading in the middle of a picture the shading card can be stuck at the end of a knitting needle. If the latter is kept in constant motion, no shadow of the needle itself will appear in the print.

A few simple shapes of shading card will cover many needs.



In shading (or dodging) parts of the image receive less exposure through being held back with a mask (A) or a hand (B) held between the lens and the paper. For spot printing – the corollary of shading – selected areas receive more exposure through a hole in a mask (C) or the cupped hands (D). To shade areas in the centre of the print suitable masking shapes (E) can be held on a wire. The spot printing mask (F) has different shaped holes which can be closed by flaps.



Painting with light. A thin beam of light, e.g. from a pocket torch fitted with a suitable snoot, darkens parts of the print by overlaying fog density. This is not the same as spot printing which makes the image itself deeper.

The shape and size of the shadow on the printing paper can be controlled by tilting the card in various directions and bringing it nearer to or farther away from the paper itself. The nearer the card is to the paper, the smaller (and the sharper) will be the shadow.

SPOT PRINTING

This is essentially the opposite of shading. While the purpose of shading is to hold back or reduce the exposure on part of the picture, the object of spot printing is to accentuate or to bring out selected portions by overprinting. The two are of course complementary, for while one part of the picture is shaded, the unshaded portions are by comparison overprinted.

Spot printing is mainly useful for giving small image portions inside the picture area extra exposure. For this purpose a card or red plastic foil is used with a hole in the middle. After exposing the whole print for the required time, this card is held in the projected beam so that the light only reaches the areas requiring extra exposure. During this time the card must of course again be kept moving.

A similar card can also be used for vignetting, which is a special case of shading to ensure that for instance in a portrait the finished picture shows in detail only the head against a more or less white background. This technique can be used not only to produce what are sometimes called "sketch" portraits, but also to cut out an unwanted or unsuitable background.

The vignetting mask can equally be used to subdue only, instead of remove, the background. If held in place for merely part of the exposure time it can serve to throw the head and shoulders, or any other chosen detail, into greater relief by reducing the exposure given to the background.

FLASHING FOR LOCAL CONTROL

The idea of shading and spot printing carried one step further leads to the technique of flashing. As used for local control, it differs from the flashing technique described on page 106 for contrast variation in two respects:

(1) Only selected areas of the print receive a supplementary white-light exposure, instead of the whole picture.

(2) The flashing exposure is here long enough to produce

visible fogging instead of being only a sub-threshold exposure.

In principle this kind of flashing is therefore a controlled method of deliberately fogging the print. We fog or darken carefully selected areas, the fogging creating its own design independently of the image formed by the negative.

Flashing is, for example, an effective method of darkening corners and edges of prints (see for instance page 408), eliminating areas that would distract attention from the main points of the picture and adding a greater range of tones to the print by enriching the blacks. Flashing can suppress out-of-focus areas, and bring tones of any depth into a badly over-exposed white sky. By using cut-out masks, new designs can be created such as soft shadows to flatly lit street scenes.

Flashing can be carried out before, during or after exposure and even during development. The most suitable point is generally after the main exposure, but before development. The only equipment required is a light source and a piece of cardboard. Almost any light is suitable which gives a controlled weak illumination. The enlarger can be used for flashing, but if only one enlarger is available, it is better to use a permanent light in a corner of the darkroom.

The light can be controlled by a rheostat or placed in a box the front of which carries panels with openings of various sizes. A low-power bulb – for instance of about 15 watts – is suitable for this purpose. This light box is set up at least 12 inches from a wall and 4 feet above a table. The exposed print is placed on the table, and shaded with a sheet of cardboard at least twice as large each way as the print. This card is then kept in continuous motion, exposing the areas of the print to be flashed during this supplementary fogging exposure.

To flash the right areas, a rough print can be used as a guide. Another method is to keep the print under the enlarger and have the negative still projecting its image on to the paper through the red filter.

An alternative way of flashing is to take a pocket torch, remove its lens and reflector, and wind a cardboard sleeve round the bulb so that the front opening in this sleeve emits a thin pencil of light. This torch can then be used to "paint" with light on to selected areas of the print.

If appropriate colour filters are placed in front of the torch bulb, this method can also be used for painting in special colour effects in prints from colour negatives.

HIGH-KEY PRINTS

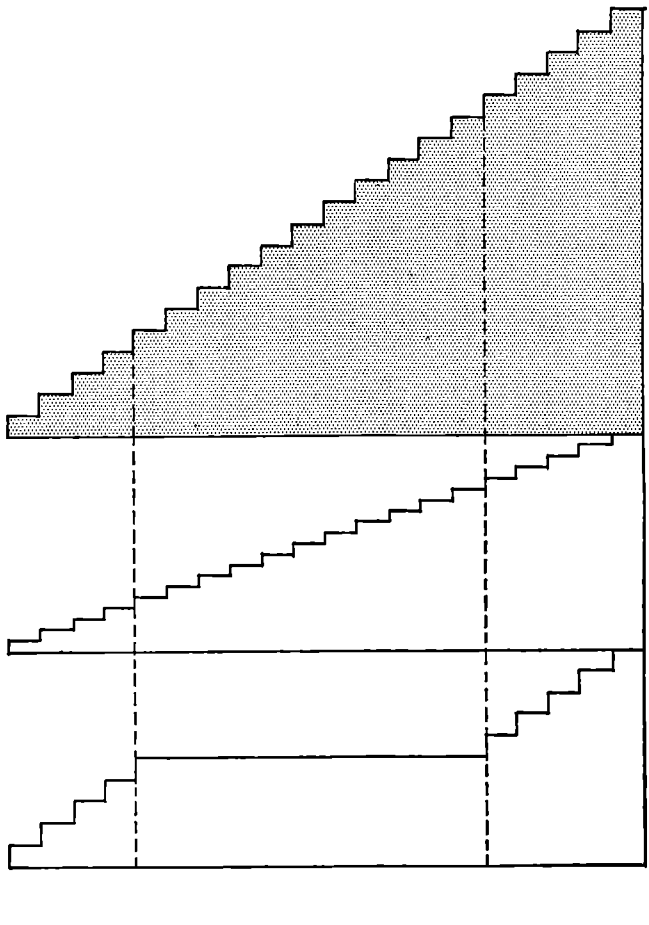
This term applies to prints which have no full black tones and consist of mainly light and a few medium greys only. Not every subject can be effectively printed in this way, for where deep shadows are actually present in the original, a high-key print would merely falsify them. High-key techniques are however frequently particularly satisfying with portraits of children and women.

The production of a good high-key picture starts in the camera and in fact demands a subject not only of predominately light tones, but of short brightness range. The highlight gradation must however be fully preserved; for this reason the negative must receive reasonably full exposure (to ensure that all tones are reproduced on the straight-line portion of its characteristic curve) and soft development. The print is then made on a soft paper grade to ensure that all negative tones print distinctly at the low end of the paper tone range. In contrast to ordinary prints where no area should be absolutely white paper, a high-key print may have completely white portions, always provided that no really dark tones are present.

LOW-KEY PRINTS

Like a high-key image, a low-key one is restricted to only part of the tone range of a print – in this case the deeper tones. Again the production of a low-key picture starts in the camera with a subject of limited brightness range. In this case adequate separation of shadow tones, from the near black to the fully black, is important, so the negative must not be under-exposed. Since the effect is intended to be heavy in the final picture, the contrast of both the negative and the print can be higher – provided there are no large areas of lighter tone than very dark grey. In printing the contrast must not however be so great that the dark tones lose their detail, so a normal paper grade is usually best.

A picture with only dark tones tends to look muddy, and therefore a low-key subject should have a few small highlight areas – for instance catch lights in the eyes of a por-



To print a negative with a very long density range (long set of steps, *top*) a very soft paper (*central* long set of steps) must be used. This leads to an undesirable compression of gradation in the print owing to the latter's limited density range. In tone separation processes some of the intermediate tones are suppressed (more strictly, overlapped) to increase the contrast of the more important highlights and shadows for a visually more pleasing result. In effect they introduce a central "platform" instead of the central section of steps (*bottom*) to retain the detail contrast with a lower overall range of tones. See page 418.

trait – to set the tone level of the print in its proper perspective. For that reason also it is not possible to obtain a low-key effect merely by overprinting a normal negative; this would lose shadow detail and kill the necessary highlights.

A low-key print can however be enhanced by flashing – painting in corners and other unimportant image areas which print too light, with the aid of the torchlight pencil as described on page 413.

TONE SEPARATION

As we saw on page 85, it is impossible to reproduce faithfully the full brightness range of a contrast scene within the tone scale of a paper print. A negative can in most cases record a great subject brightness range within the film's considerable density range. If however we attempt to print such a negative on a soft paper grade, the tone gradations are so compressed that the print looks dull and flat, even though it may have all tones from pure white to full black.

We also noted that to obtain a print of acceptable tone gradation from a long-range negative (i.e. one which has recorded a great range of subject brightnesses, even though the negative gradation may be comparatively soft) we usually have to sacrifice either or both ends of the tone range (page 85).

To print such a negative satisfactorily, there is however, yet another way out: we can retain the tones at both ends of the scale if we sacrifice part of the tone range in the middle.

Thinking in terms of our staircase analogy once more, the negative image may be represented by a very high staircase, while the positive one must be compared with a relatively low one. The two staircases cannot be superimposed so that each step on the one will coincide with one of the other, and equally, this difference between the tones of a negative and positive print cannot be removed in printing or enlarging. In photographic terms, the negative range is too long to be accepted by the printing range of the paper used for it.

If all the negative steps are scaled down in height to accommodate the same number of steps within the positive staircase, the contrast between each pair of tones in the printed positive is considerably less than that between a corresponding pair of tones in either the negative or the original subject. This is particularly true of the highest lights

and darkest shadows, which are usually more important to the picture than the middle greys, since the appearance of a print is very much more dependent on the correct reproduction at the ends of the tone scale than at the centre.

We can however produce a low staircase (representing the positive print) in which the steps are just as steep as those in the original higher staircase symbolising the negative, but with a platform halfway up the slope. We here leave out the central portion of the steps in order that the height of each step present is identical with that of the higher (negative) staircase.

The same process may be used in enlarging by arranging that the highest lights and darkest shadows are shown in good contrast, while the middle grey tones of the print are more or less disregarded. What happens is that the upper part of the lower end of the staircase overlaps the lower part of the upper end. That is, tones which should be different are in fact similar.

Strictly speaking this is a distortion of tone reproduction. But it is not entirely out of tune with the way we see things. For our eyes also can register only a limited brightness range. But as we perceive mostly by letting the eye rove over the scene observed, the eye constantly adapts itself to the brightness of what it sees. So the sense impression of dark details of a scene are not much less intense than those of bright details which are taken in at a different instant.

As applied to enlarging, such a process is simpler in theory than in practice and involves splitting up the original negative into two so-called separation negatives which record the brightest highlights and the deepest shadows respectively. For this reason the technique is known as tone separation, and there are a number of variations, mostly based on a procedure originally suggested by *A. Person.*

The two negatives are then enlarged in succession but in register on to a single sheet of paper with exposures chosen to print correctly the highlights and shadows respectively from the appropriate negative.

The practical steps of the process are as follows.

1. From the original negative with its excessively long tone range print the positive transparency with a sufficiently short exposure to register just the shadows in their full tone detail. The highlights here remain clear transparent film.

This we shall call the *shadow positive.* A positive film, lantern plate or even low-speed negative material (preferably non-colour sensitive to simplify handling in a darkroom) of reasonably high but not excessive contrast can be used.

2. From the same negative make a second positive transparency but with sufficiently full exposure to show full detail in the lightest highlights. This is our *highlight positive.* The shadows will necessarily be completely blocked up and opaque.

3. From the shadow positive No. 1 prepare a new negative on a contrasty material as used for the positives, but developed also in a contrasty developer (for example, formula No. 21 on page 337). This should receive sufficient exposure to show full shadow detail; the highlights can be very dense. This is the *shadow negative.*

4. From the highlight positive No. 2 make another negative, this time with a very short exposure, just sufficient to record the highlights in full detail. This is the *highlight negative.* The shadows will be detailless and transparent. This negative should be developed in a soft-working developer (for example, formula No. 20 on page 337), with the development time kept short.

5. Enlarge the shadow negative No. 3 onto a sheet of bromide paper, giving a normal exposure to allow the shadows to print through. The highlights would not with this exposure register. The paper is not however developed yet at this stage.

6. Print the highlight negative No. 4, giving a very short exposure. This enables the highlights to print through in the previously unexposed areas of the paper, while the exposure is too short to add much to the shadow density produced in step 5.

7. Finally, the print is developed in the normal way.

If the original negative is of medium to large format (i.e. (6 × 6 cm or $2\frac{1}{4} \times 2\frac{1}{4}$ inches) the intermediate positives and separation negatives can be made by contact printing in a printing frame (page 477). Alternatively, they may be projection printed in the enlarger at same-size or slightly enlarged, to yield separation negatives which are easier to handle. However, the magnification must be absolutely identical to ensure accurate register at the final printing stage.

The exposures required for steps (5) and (6) will have to be determined by separate tests to ensure that the shadows

print through fully at step (5), and the highlights have just the right depth at stage (6).

For the final combination print the images must be superimposed in accurate register on the paper. This is less difficult than it sounds, for it is usually possible to make register marks in pencil on the paper. A clearly defined detail in the negative image is marked with a soft and sharp pencil; the pencil trace can later be rubbed off during development. Alternatively, a couple of registration marks can be scratched into opposite sides of the original negative (or on parts of the image which are not required in the final picture), and the final print made a little larger than required. These registration marks can be trimmed off afterwards.

During the first exposure – step (5) – these marks are traced in pencil on the bromide paper, and by using the orange or red filter over the enlarger lens (page 174), no special difficulty is involved in bringing the paper under the exact points necessary for register when the second exposure is to be made.

Registration becomes easier still if an enlarger with register pins in the negative carrier (page 192) is available. In this case the highlight and shadow negatives are superimposed visually in exact register and then punched together along one edge (outside the picture area). As each negative is inserted in succession in the negative carrier, the register pins automatically keep it in exactly the same position. In this case the paper on the baseboard must not be moved between the two exposures. Similarly, if a baseboard with register pins is available, the films for making the intermediate positives can each be prepunched, and the images will then be accurately positioned relative to the punch holes.

Three somewhat shortened alternative procedures are:

(a) With medium-size to larger negatives the original negative – if it was fully exposed in the shadows and has recorded them with full contrast – may be used directly as the shadow separation negative. This saves steps (1) and (3) above, but the highlight positive and negative must be made by contact printing or very exact same-size projection.

(b) The separation negatives can be made by reversal processing (page 442), or – if the original negative is

used as the shadow negative – only the highlight negative need be prepared in this way. Some tests are however necessary to establish the correct exposure and processing conditions to get a highlight negative of the required characteristics.

(c) From miniature negatives it is usually most convenient to make a full-range intermediate transparency. From this a heavily exposed contrasty shadow negative (No. 3 above) with full shadow detail and virtually opaque highlights is made, as well as a lightly exposed and softly developed highlight negative of the characteristics detailed under (4) above. These are then printed in register as before.

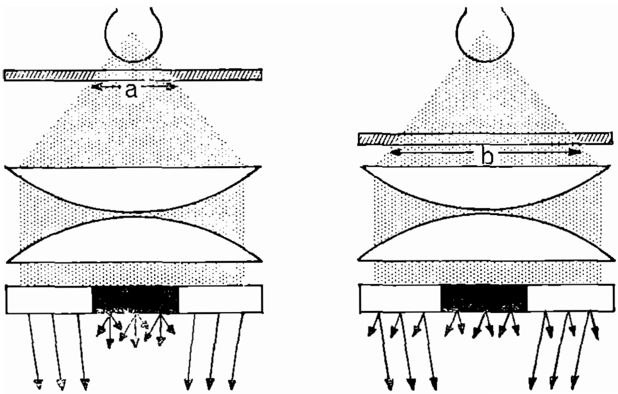
Various other modified tone separation procedures have been described from time to time, and similar results can also be obtained by certain controls during print development (page 437). An extreme case of tone separation is posterization, which is used to obtain certain graphic design effects.

CONTRAST CONTROL IN THE ENLARGER

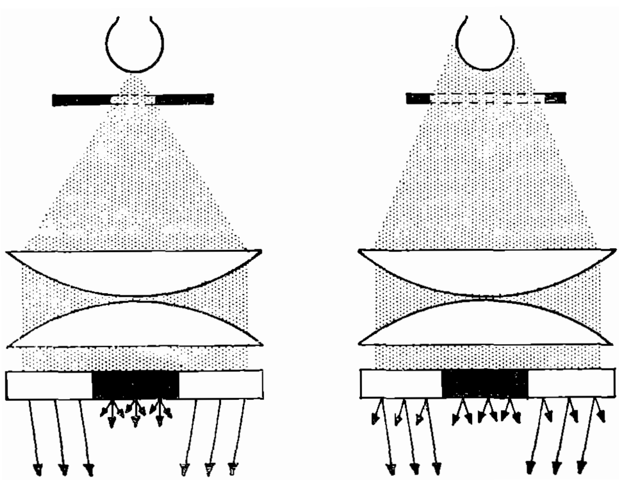
Through the use of variable contrast papers (page 105) and of sub-threshold flashing (page 106), one type of paper can give prints of different controlled contrast.

We also know that as a result of the Callier effect (page 127) there is an appreciable difference between the contrast of an enlargement produced with a point-source light and condenser, and one made by diffused enlarger lighting. The principles underlying this difference have also been utilised to control the gradation in an enlargement. If these methods are mentioned here somewhat in passing, that is mainly because contrast control by variable contrast papers and by flashing is considerably more convenient in practice.

The simple way of varying the contrast of the image (provided it is a silver image and not a dye one of a colour negative) is to have a movable diffusing screen in the enlarger between the condenser and the light source. When this screen is close to the condenser, the lighting effect is comparatively diffused with correspondingly lower contrast. As the screen is moved nearer to the light source, the diffusing effect is reduced and thus the contrast somewhat increased.



A diffuser placed very close in front of a point source lamp turns the latter into a source of diameter (a) still capable of increasing the contrast of the negative by the Callier effect (*left*). Bringing the diffuser nearer to the condenser increases the effective size of the light source to (b) and the enlarger lighting becomes softer (*right*).



A similar control of illumination is obtainable with an adjustable iris in front of a comparatively large opal lamp. With the iris closed down, the effective light source as far as the condenser is concerned is small (*left*); with the iris fully open the light source is larger and the light softer (*right*).

Enlargers have also been patented with variable optical and lighting systems to produce the contrast variation on the same paper grade.

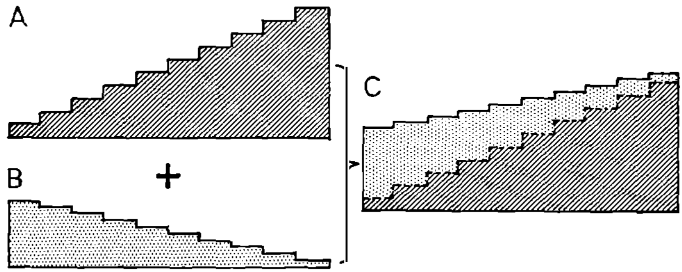
A method of obtaining a similar result without any change in the lighting system employs an enlarger with condenser and pearl bulb, and an iris diaphragm in the light path between the condenser and the lamp. If this diaphragm, situated close to the lamp, is closed down, only the direct central rays from the lamp are used and the illumination corresponds in principle to condenser lighting with virtually a point source, leading to higher image contrast. If on the other hand the direct central rays are cut out or intercepted, and only the marginal rays from the lamp used, the result is heavily diffused light with softer gradation. This is obtained not merely by opening the diaphragm fully, but by also placing a diffusing screen between the lamp and the condenser.

CONTRAST CONTROL BY MASKING

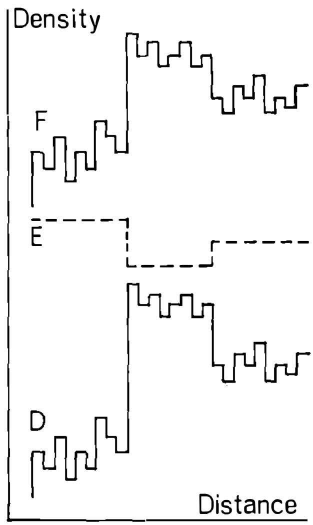
The contrast of negatives can be controlled within very wide limits by the use of masks. The mask is a very soft and thin positive transparency made from the negative by contact printing. If this transparency were to have the same contrast as the negative, the two would cancel out when placed in perfect register. However, a mask of lower contrast reduces the negative contrast, so this method permits contrast control of negatives to practically any degree.

At first sight the effect of combining a negative with such a positive mask does not differ appreciably from developing the negative to a lower contrast, or indeed printing it – where possible – on a softer paper. Straightforward masking does not overcome the problems of matching a great subject brightness range to the more limited tone range of a paper print. If however the mask is made slightly unsharp, several advantages accrue.

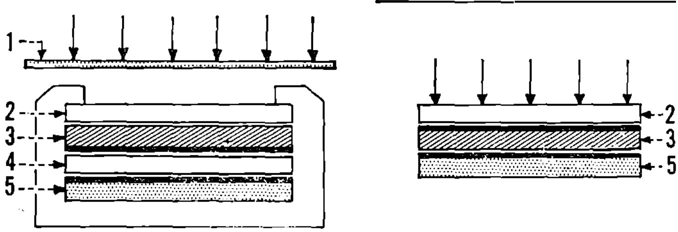
In the first place, the mask becomes easier to register with the original negative – superimposition of a blurred image can be less precise. Secondly, an unsharp mask actually improves detail and definition in the enlargement. The reason for this is that image detail is in most normal negatives overlaid by a very low-contrast thin blur, due to halation and irradiation. The unsharp mask tends to cancel this blur, and



Above: Superimposing a low contrast positive image B on a high contrast negative one A yields a negative C of reduced contrast.



Right: In this simplified plot of density across an image the steps represent different tones. The small steps along the distance axis correspond to fine detail, the larger intervals to coarse detail. An unsharp positive mask E records only tone differences of coarse detail; when superimposed on a contrasty negative D, the result is an image F of reduced overall contrast, but the same detail contrast as in the original. (After D. A. Spencer's *Colour Photography in Practice.*)



Making an unsharp mask. The simplest way is in a printing frame (*left*). The heavy lines represent the location of the emulsion surfaces. 1, tissue paper or diffusing sheet; 2, glass of printing frame; 3, negative; 4, clear spacer film; 5, masking film. The negative film base itself can serve as a spacer in the arrangement shown *right.*

leaves a sharper image of reduced contrast. To compensate for the flattening effect of the mask, a harder paper grade is chosen, which increases the contrast of the fine detail and improves its rendering.

The removal of the detail blur by masking in effect improves the acutance (page 45) of the image.

If the unsharp mask is strongly blurred, it no longer increases the acutance of fine image details, but still improves reproduction by compressing the overall contrast of the negative while preserving the detail contrast. This is analogous to (but not identical with) the results of tone separation described on page 418.

Making an unsharp mask is quite simple. The negative is placed in a printing frame together with a low-speed film or plate, separated by a piece of thin transparent plastic film about 0·008 inch (0·2 mm) thick. (A piece of unexposed and fully fixed out photographic sheet film will do admirably.) With small negative formats this plastic spacer film can be thinner – sufficient unsharpness is often produced even by placing the negative with its back in contact with the emulsion side of the masking film. The printing frame is laid out on the enlarger baseboard. A sheet of thin white tissue paper is arranged about 3 or 4 inches above the frame. This sheet must be much larger than the negative, and provides a diffused light source for printing when the enlarger is switched on (without a negative in the carrier).

In registering the negative with the developed and finished mask, the two are best arranged in the same way as they were in the printing frame, using the spacer sheet of film if this was employed in making the mask. After registration the whole sandwich can be secured with a small piece of transparent tape.

This type of masking is widely used when making reversal colour prints from colour transparencies in more advanced professional colour laboratories. The brightness range of the transparency is generally too great to be reproduced adequately on paper (see page 85); the mask reduces this brightness range to something that the paper can handle without distorting the colour values or losing colour saturation in the lighter and darker tones.

Various more complex masking systems exist and are employed in certain special fields of colour photography and

reproduction. They can there not only correct contrast, but also colour reproduction faults inherent in colour processes using dyes or pigments. The orange-red tint on some colour negatives is an integral masking image of this kind, produced automatically in the negative during processing. The orange tint is in fact made up of positive masks for the magenta and the cyan images of the colour negative.

ELECTRONIC MASKING

A method of controlling both overall and detail contrast at will uses a special enlarger with a flying spot scanner as its light source. First employed in the LogEtronic enlargers, this uses an electron beam which scans over the fluorescent face plate of a cathode ray tube in a regular pattern. This tube plate is arranged immediately behind the negative. The light spot produced by the electron beam illuminates the negative point by point during the printing exposure.

The main advantage over a continuous light source is that the light coming through the negative can be controlled also point by point during the scan. For this purpose a photo cell monitors the light passed by the various negative points as the flying spot scans them, and in turn adjusts the brightness of the flying spot itself. This provides considerable scope for contrast control.

The photo cell, usually a photo multiplier tube, may be located either underneath the printing paper on the easel or receive its light through a beam splitter which diverts about 5 per cent of the light flood in the enlarger system. While the photo tube is set up in the same way as an integrating exposure measuring system, the light it actually receives at each instant corresponds to the light coming through the negative at one particular spot. Hence the photo tube continuously measures the image density of the negative point by point.

The photo tube controls the intensity of the scanning spot and in this way the contrast of the resulting print. This is done by feeding the output of the tube into an inverse feedback amplifier. This amplifier is linked with the circuits controlling the electron beam. When the photo tube registers a high light intensity (as the flying spot scans a thin negative detail), the feedback reduces the spot intensity. So thin areas receive less exposure than they would otherwise do. But

when the photo tube output drops, the feedback amplifier increases the electron beam power, to push more light through dense negative portions.

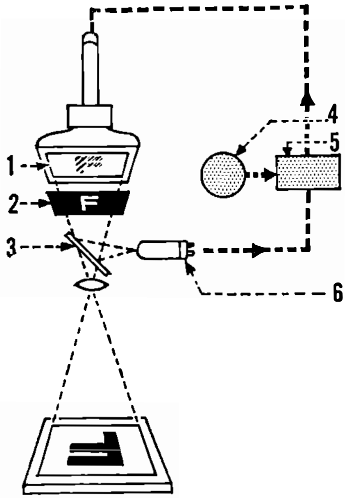
So what takes place is an automatic and simultaneous shading and overprinting of various parts of the negative, according to their individual densities. This reduces the contrast of the print, so that even negatives of extreme density range can yield acceptable prints on a normal or even hard grade of paper. And even the problems of accommodating a great negative brightness range on the paper tone range are solved by the unsharp masking function of the flying spot scanner.

To put it in another way, the negative is printed with a light source which corresponds to a luminous positive image. This takes over all the functions of an unsharp positive mask produced as described on page 414, except that the light mask is formed automatically during the printing process and requires no preparatory work or processing. It is also automatically related to the negative and in perfect register with it.

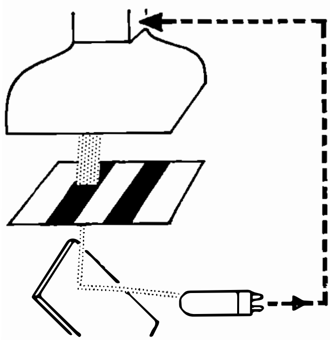
Adjusting the feed-back of the amplifier controls both the mask density and contrast. With zero feedback the printing effect is the same as with a continuous light source, for the scanning spot remains uniformly bright all the time. Negative feed-back, as just explained, adjusts the spot brightness to compensate for negative density variations. With 100 per cent negative feed-back the compensation would be complete; in theory this should give a completely uniform print tone with no recognisable image.

With more than 100 per cent negative feed-back the image would be reversed: a negative could in this way yield a negative. With positive feed-back on the other hand, the print contrast is increased. Electronic printing thus offers a virtually unlimited degree of contrast control. In practice, electronic enlargers can handle negative density ranges up to about 3·0, and compress these to a range of 0·1 to 0·3 on a print.

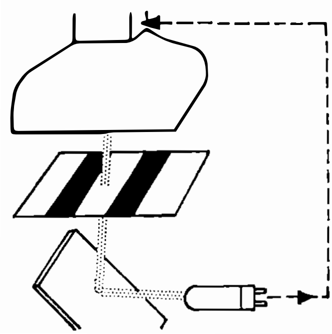
By itself this contrast compression does not yet solve the problem of preserving good separation of the image tones. But the latter requirement is met in part by the unsharp mask characteristic of the flying spot scanning system. The spot has a definite physical size (adjustable in practice



In the electronic enlarger the light source is not a uniform continuous one, but a flying spot of the fluorescent face plate of a cathode ray tube. This scans the negative area in an interlaced pattern. The intensity of the scanning spot can be varied according to the density of the negative detail being scanned at any instant (page 427). 1, cathode ray tube; 2, negative; 3, beam splitter; 4, contrast control adjustment; 5, inverse feedback amplifier; 6, photo tube.



When the spot scans a dense negative area, little light reaches the photo tube. The tube output, through the inverse feedback amplifier, then increases the intensity of the scanning spot.



When the spot scans a thin negative area, the greater light intensity reaching the photo tube causes the spot brightness to decrease. In this way the local variations in the brightness of the printing light in effect generate a positive mask of any desired contrast.

between 1.5 and 6 mm). Any detail smaller than the spot size therefore does not have its contrast depressed. The spot size is a measure of the unsharpness of the masking effect.

With a large spot and appreciable feed-back we thus get an effect similar to tone separation: the electronic printer automatically compensates for tone differences of large areas, but preserves the contrast of small ones. If the spot is kept small and the feed-back (contrast control) moderate, the effect becomes more that of employing a slightly unsharp mask: the acutance of small image detail is increased. This is particularly useful when printing negatives with very fine detail, and electronic printers of this kind are therefore used – among other fields – for printing negatives of aerial photographs where fine detail resolution is important.

The result of the finite spot size is also a fringing effect characteristic of this kind of tone control. This results in the dark side of the border between a light and dark area becoming darker, and the light side lighter. It arises because as the spot scans a boundary of the image from light to dark, the light reaching the monitoring photo tube changes gradually, but the feed-back circuit reacts instantly. So the boundary of the shadow area begins to receive more exposure than the shadow region just traversed by the spot. Similarly the edge of the highlight area gets less exposure than the region covered by the spot immediately afterwards.

The photo tube monitoring the light coming through the negatives can also control the overall exposure, by suitable controls which set the spot brightness according to the sensitivity of the enlarging paper used. In this case the actual exposure time is constant. Alternatively, if the instrument has a second photo multiplier tube which terminates the exposure after a certain amount of light has fallen on it, we have an automatic exposure control system similar to that employed in masking frames with built-in photo multiplier tube (page 278).

While an electronic enlarger on this principle is its most versatile application, flying spot scanners can also be used for contact printing. In this case the negative is held in close contact with the paper, and the light source is again the cathode ray tube with its scanning spot. The light is monitored by a photo cell placed behind the printing paper to measure the light coming through the latter.

Electronic enlargers of this kind have also been designed for colour printing. Here the negative is exposed successively through a red, green and blue filter by the usual tricolour method. During each exposure a photo tube behind a complementary filter (cyan for the red filter exposure, magenta for the green filter exposure and so on) monitors the light coming through the negative. By suitable controls the feedback to the scanning spot can be adjusted separately during each of the three exposures – which permits not only colour balance control but also automatic colour masking to compensate shortcomings of the dyes used in the colour material.

Other systems of automatic masking control have also been proposed. In one method the light source is a phosphorescent screen excited by ultra-violet radiation. The negative in front of this screen is irradiated by infra-red rays which tend to quench the phosphorescence. The higher the negative density, the less infra-red radiation gets through to the phosphorescent screen and the brighter the screen stays behind that negative area. The screen therefore again builds up an unsharp luminous positive image of the negative to act like an unsharp mask.

MODIFYING TONE VALUES BY RECOPYING

Finally, a comparatively simple masking system is worth mentioning, which has an effect similar to the tone separation process (page 418) but without requiring two enlarging exposures in register. The final negative is simply enlarged in the normal way.

For this purpose the original negative must not be too thin. It should give a reasonably good range of tones when enlarged on a normal bromide paper. However, if for instance the shadows print too heavily – possibly through slight underexposure or in a picture taken against the light – a positive is prepared from the negative on an extra-hard process film. The exposure is adjusted so that development in a contrasty developer reveals the shadow detail in the film, while the medium tones and high-lights appear only weakly – similar to the shadow positive No. 1 on page 419. From this positive a shadow negative is prepared by contact copying on a normal contrast film (for instance a fine grain negative material on a thin base). The exposure is now selected so that

the deepest shadows show perceptible density, but the general appearance of the negative is thin and soft.

This shadow negative is now bound up with the original negative in register, and the sandwich mounted preferably between glass plates. The combination negative may now be enlarged, using a soft-grade paper. What we have in effect done, is to mask only the shadows of the original negative, thus moving the shadow tones nearer to the highlights, but without flattening the contrast appreciably.

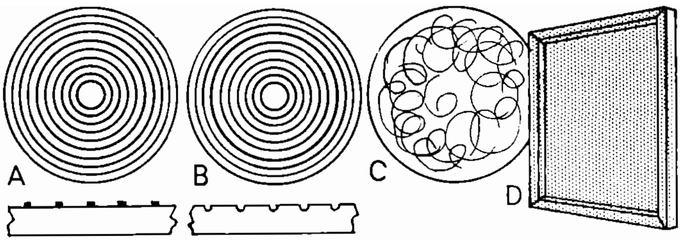
Alternatively, where the highlight gradation of the negative is too flat (e.g. through overexposure) we can improve highlight contrast by masking. This involves the preparation of a highlight negative as in tone separation (page 420). A positive is prepared from the original negative, with the highlights well-defined and in normal to contrasty overall gradation. This means reasonable development and not too weak a result. From this positive we now make a highlight negative on a thin-base process film, giving short exposure but full development to record the highlights with good contrast, leaving the medium tones and shadows virtually transparent.

This highlight negative is combined with the original negative exactly as in the previous case, and the enlargement made on a soft paper.

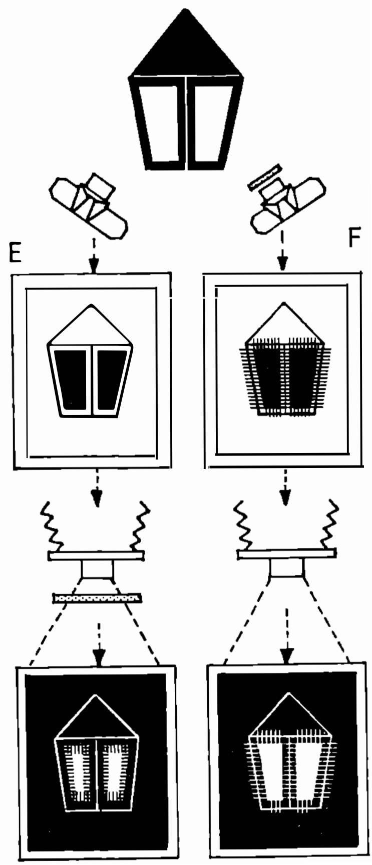
Finally, to obtain a similar effect to that provided by the Person process, in which shadow detail and highlights are emphasized at the expense of the middle tones, separate shadow and highlight negatives are prepared and combined. In this case the shadow negative will be contrasty, with a highlight negative of more normal gradation. Thus the shadow negative is produced from a hard positive on a contrasty process film, and the highlight negative made on a normal-contrast material. In both negatives the middle tones will be somewhat soft and lacking too heavily defined detail.

SOFT FOCUS

For pictorial purposes it is sometimes desirable to tone down the characteristic pin-sharpness of the image produced by the camera, and to introduce a certain amount of softness into the picture. There is a great difference between lack of focus and softness of focus, and the effects of the two do not resemble each other in any way.



Above: Soft focus attachments can consist of a glass or plastic disc with embossed rings **A**, engraved rings B, with a smeared-on ring of grease C, or a piece of muslin or net fabric D stretched on a frame. The exact diffusion effect obtained is not necessarily the same with these devices.



Right: The diffusion effect depends also on whether it is introduced during the camera exposure or during enlarging. Diffusion during enlarging of a sharp negative E produced in the camera makes the dark areas in the picture spread into the light ones: the effect is soft and subdued to sombre.

If the diffusing device is used in front of the camera lens, this spreading of dark into light areas takes place in the negative F. On printing this, the diffusion in the positive appears as a spreading of light into dark image areas – the effect is dreamy and ethereal.

When a lens is incorrectly focused, each image point becomes a relatively large disc (page 44). This is even in brightness over its whole area, and the image simply looks blurred. A soft-focus device, on the other hand, produces two images: a normally sharp one and an overlaid kind of halo which varies in intensity with the exposing light at that image point. The result is a print showing a sharp yet diffused image, in which the outlines of objects are not fully sharp, though there is no real loss of detail. (Acutance is reduced, but resolution only very slightly – see also page 47.)

Soft focus can be used in the camera as well as in the enlarger, and the effect of the two is quite different. Diffusion during the camera exposure makes light portions of the scene spread into the dark areas, and the result is a luminous dream-like effect. In the enlarger on the other hand, the shadows spread into the lighter areas of the picture. Although the result is here not quite so natural, soft focus during enlargement often yields satisfying images with emphasis on light and shade with a contrasty subject.

To obtain the luminous camera-type soft focus in an enlargement, we can make a duplicate negative via an intermediate transparency. The transparency is printed in full sharpness, but is softened by diffusion during reprinting on the duplicate negative material. (Reversal processing cannot be used here, and the negative must of course be prepared by projection printing in the enlarger. The intermediate transparency may be produced by contact printing.)

The softness of focus discussed can be produced in a number of ways. The simplest is a piece of open-weave fabric such as muslin, tulle or a piece of old nylon stocking. This is stretched on an open cardboard frame and held in front of the lens during the exposure. The structure of the fabric may influence the result: a circular mesh gives a different effect from a square one. A white fabric slightly reduces the exposure required, and a black one increases it.

Diffusion discs are also available commercially, and consist of glass or plastic discs with embossed or engraved concentric rings at regular intervals. White or black rings on plain glass discs may also be used, in which case more diffusion results from the former than from the latter. A soft-focus disc can also be home-made by taking a sheet of plain glass and smearing thin rings of grease over it.

The degree of diffusion introduced into the image depends on the type of device used, and various grades are obtainable to produce different effects. It is also possible to vary the degree of diffusion by using the device only for a part of the exposure instead of the full time.

Two important results of diffusion and soft focus should be noted here. The first is that grain is largely suppressed in the print, and the second is that the contrast of the print is always softened to some extent. Where strong diffusion is employed, it may be desirable to use the next harder grade of paper.

Though soft focus can give very pleasant results when used properly, it is not suitable for every photographic subject. For this reason it should be used with caution on specially selected negatives, and not applied indiscriminately to every print produced.

TEXTURE SCREENS

Special effects can be obtained by using screens or other devices which break up the image into dots or lines in a manner resembling the effect of a half-tone screen used in process work.

Generally such a screen is used in intimate contact with the paper on which the print or enlargement is made.

The simplest screen of all is tissue paper which gives a soft result and the appearance of a certain graininess which breaks up the whole image. The effect naturally depends on the thickness and the structure of the tissue paper used. For landscapes and portraits a very thin paper should be chosen with a very fine even grain. Coarse paper is suitable only for very large pictures.

After sharply focusing the image on the enlarger baseboard, the enlarging paper is placed in position, the tissue paper laid on it and the whole covered by a sheet of spotlessly clean and polished plate glass. The transparency of the tissue paper should be such that only a slight increase in exposure time is required.

Tulle, muslin and various other materials can also be used (for example a piece of discarded nylon stocking). The best results are usually obtained with screens available specially for a purpose. These are produced in a variety of patterns and grains, impressed or printed on clear plastic sheeting.

The patterns may be regular (lines, dots etc.) or irregular. There are for example screens which simulate an effect of brushmarks on the print, a little like oil painting, while others imitate the appearance of etchings, the surface of canvas etc. All these screens are used in the same manner as the tissue paper and usually in close contact with the photographic paper. In most cases a plate glass for ensuring this contact is advisable. The necessary increase in exposure when using such screens must be determined by trial and error.

Texture screens can also be prepared photographically, for instance by photographing surfaces of stonework, areas of sand, fabrics and innumerable other more or less regular natural textures. The negatives are then enlarged on a suitable-sized positive film with an exposure just sufficient to make the texture pattern show up. It should be considerably softer in contrast than the actual negative being printed. If a negative screen is required, the transparency film may be processed by reversal. Generally it is best to make the texture in a large format camera so that the final texture pattern does not become too coarse.

Texture screens and texture images can also be combined with the negative in the carrier of the enlarger. In this case the texture should be particularly fine, since it is enlarged together with the principal negative image.

Finer Points of Processing

As emphasised before, normal enlarging routine demands standardised processing conditions. In most cases control of tone and contrast is more conveniently achieved when exposing the enlargement. Nevertheless there are various processing procedures for special effects, listed here with once more the reservation that they are the means to certain less usual ends.

CHEMICAL METHODS OF MODIFYING GRADATION

Results reminiscent of tone separation can be obtained at the processing stage by a procedure of overexposure followed by chemical reduction. This process has been termed "brometching".

The first step is to overexpose the enlargement heavily, some three to six times normal. The development time is also increased by about 50 per cent. After development, and before fixing, the print is quickly rinsed and transferred to the following reducer:

32 – ETCHING REDUCER

Solution A		
Sodium chloride (common salt) 25% sol.	¾ ounce	18 ml
Sulphuric acid, 10% sol.	½ ounce	12 ml
Water to	40 ounces	1000 ml
Solution B		
Potassium permanganate, 2·5% sol.	1½ ounces	37 ml
Water to	40 ounces	1000 ml

For use take equal parts of A and B

When the desired effect is reached – i.e. the highlights are nearly clear, the print is thoroughly washed and fixed in an acid fixing bath. The latter should contain plenty of potassium metabisulphite to clear the permanganate stain. The

method can produce pictures with a long scale of tones and good deep blacks. With rough surface papers the paper grain tends to stand out visibly, giving the print the appearance of an etching. Smooth surfaced papers are not suitable for this process.

The print gradation may also be modified by another method involving redevelopment. Here the print is again overexposed and overdeveloped to a point where shadow detail is completely blocked up.

After fixing and thorough washing the print is treated in the following bleacher until only the detail in the shadows is clearly visible:

33 – HALOGENIZING BLEACHER

Potassium ferricyanide	$1\frac{3}{4}$ ounces	40 grams
Potassium bromide	1 ounce	25 grams
Water to	40 ounces	1000 ml

This solution may be diluted with one to two parts of water if the action is too fast to be easily controlled.

The print is then washed and redeveloped in a diluted developer until the details in the highlights appear. Finally the print is again fixed, washed and dried in the usual way.

MOIST EXPOSURE

A method of tone control which has the advantage of being comparatively simple in not requiring either masking images or special solutions consists of exposing the paper to the projected negative image after soaking in developer. This gives images of a somewhat different character from that obtained by printing on a soft paper grade, but it does have the effect of compressing the tone range of the print.

The unexposed enlarging paper is first soaked in developer for about a minute, then taken out, laid emulsion side up on a glass plate and all excess liquid removed by blotting paper, a piece of chamois leather or other means. No drops or streaks of liquid must be left on the surface. The paper on its glass plate is now given a first exposure which should be just long enough for the darkest shadows of the picture to appear. As soon as these are visible, the exposure is stopped and the slow development allowed to proceed for one to two minutes (without removing the paper from the enlarger

baseboard) until the shadows are developed. The black silver in these areas then acts as a screen to the underlying silver bromide during subsequent exposure. The shadows should not be too dense, because they will darken slightly more during the subsequent dish development.

Now follows the second and sometimes rather long exposure, which must be adequate to ensure that the highlights are correctly exposed. Those parts of the paper which develop after the first exposure are unaffected by this exposure, as the developed image of the first exposure protects them. As soon as the exposure is considered sufficient, the usual dish development follows until the highlights appear, without the shadows being perceptibly altered.

If the first and second exposure have been correctly estimated, the finest details in the highlights are visible without the shadow details being blocked up. By this method it is possible to bring the major part of the tone scale of the negative within the exposure range of the paper, mainly at the cost of the middle tones. The effect is very similar to that obtained by tone separation (page 418) which aims at a light result. In both cases the fact that, from a pictorial point of view, the middle tones are less important than the highlights and shadows is taken advantage of.

The result depends not only on correct estimation of exposure times, but also on the properties of the developer which must have the right concentration, so that the correct density is developed in the shadows to protect them during the subsequent longer exposure. This concentration is best found by trial and error with varying dilutions. The developer must be clean working and absolutely free from fogging. For this purpose the use of an anti-foggant (see page 331) is strongly recommended.

PSEUDO-SOLARIZATION

This is a technique of partial reversal of the image, produced by exposing the paper briefly to diffused white light during development. This white-light exposure must take place when the shadows of the image are already developed, and protect the areas underneath them from further exposure. The partly developed image thus acts as a mask, while the fogged areas develop up strongly as development is continued after this fogging exposure.

At the same time a light line is formed at the boundaries between light and dark areas of the original image. This is due to the fact that bromide ions, liberated during development of the silver image, accumulate at the boundaries between shadow areas developed before the fogging exposure, and highlight areas developed afterwards. The bromide retards development along these boundaries, so producing the lighter outline. The outline appears most distinctly along boundaries between very light and very dark areas, and is characteristic of pseudo-solarization (which is correctly known as the Sabattier effect).

The result obtained is variable within wide limits and depends on the following interrelated factors.

(1) The basic exposure of the print. This must neither be so long that the shadows build up too rapidly in the developer before the fogging exposure, nor so short that the shadows do not appear at all in sufficient strength.

(2) The first development (before the re-exposure). If this is too long, the fogging exposure has little or no effect and the characteristic outlines are missing. Too short a first development produces insufficient image to prevent general overall fogging.

(3) The fogging exposure. If this is inadequate, the effect is largely lost; too much fogs the image all over.

(4) Second development after fogging. This must proceed sufficiently far to produce the light contours around subject outlines, but not so far that the outlines get blackened by the developer as well.

Pseudo-solarization is more than just darkroom dabbling, for it is used, in conjunction with other tone control techniques, for a variety of graphic effects and abstract designs (see also pages 398–400). Pure outline effects based on pseudo-solarisation are obtainable with special equidensity materials (see pages 398 and 489).

LOCAL REDUCTION

While in general it is rarely worth while to save an excessively dark print by chemical reduction (making a new print is much quicker and simpler), the character of the picture can be modified by partial reduction of selected areas. Thus dark and detailless shadows can be lightened, or undesirable image portions removed altogether from the print.

Not every reducer is suitable for this purpose; it must not interfere with the gradation or tone scale of the picture.

A suitable formula is:

34 – PERMANGANATE REDUCER

Potassium permanganate, 0·4% sol.	60 minims	3 ml
Sulphuric acid, 0·2 % sol.	60 minims	3 ml
Water to	4 ounces	100 ml

The previously soaked print is laid on a glass plate, excess moisture removed and then the parts to be reduced painted over with the reducer solution. A camel-hair brush or a plug of cotton wool can be used.

As the reduction proceeds, the print begins to be stained brown. This disappears completely when the print is placed in an acid-fixing bath or treated in a 5 per cent solution of potassium metabisulphite.

Another reducer which is particularly suitable for local action uses a mixture of iodine and thiocarbamide. This is easily controlled and does not affect the tone of the picture.

35 – IODINE REDUCER

Solution A		
Iodine	175 grains	10 grams
Methylated alcohol	10 ounces	250 ml
Solution B		
Thiocarbamide	$\frac{3}{4}$ ounce	20 grams
Water to	10 ounces	250 ml

The methylated alcohol should be the colourless industrial variety, not the normal purple methylated spirit.

For use mix equal parts of solutions A and B. Then apply the mixture by means of a brush to the area of the print to be reduced. To retain the acting reducer in a moist condition, the brush can be dipped into alcohol and used to moisten the area being treated. When the action is judged to have gone far enough, the print is plunged – without intermediate washing – into a fixing bath. This stops the action of the reducer; after fixing wash the print well.

If necessary, glycerine may be used to thicken the reducer and prevent it from encroaching on areas of the print where reduction is not desired.

There are occasions when it would be convenient to produce a negative image in place of a positive one and so eliminate the stages of making intermediate positive transparencies. This is useful in some of the methods of tone separation already described (page 418) as well as in various other procedures for special effects (page 493). Equally, direct positives are useful in the reproduction of documents for it is much easier to read black print on a white background than vice versa.

For document copying by contact printing direct positive papers are also available which yield a negative image from a negative and a positive one from a positive by straightforward processing (page 499).

Another useful application is the preparation of direct positive black-and-white prints from colour transparencies and from 16 mm reversal film.

The above examples show that we may have to deal with two separate cases, namely the preparation of a line or high contrast positive on the one hand, and a continuous-tone one on the other.

Naturally the choice of paper and of the details of the process also play an important part.

Reversal processing consists of the following steps:

1. The exposed paper is first developed in an energetic developer.

2. The image produced during this first development is next completely dissolved in a suitable silver solvent.

3. The remaining silver bromide which was not affected by the first exposure is now fully exposed and developed to provide an image.

Obviously the nature and quality of the final image is determined by the quantity and structure of the silver bromide left behind after the first development and the removal of the first image. This in turn depends on the exposure and the first development, and these two factors require some trial-and-error experimentation to give the most suitable result.

For the first development of line subjects Formula No. 36 below is a suitable developer. For continuous-tone subjects a normal MQ-developer may be used, for instance Formulae Nos. 12 to 16 on page 334.

36 – FIRST DEVELOPER FOR HIGH CONTRAST

Solution A

Sodium sulphite, anh.	4 ounces	100 grams
Hydroquinone	350 grains	20 grams
Potassium bromide	70 grains	4 grams
Water to	40 ounces	1000 ml

Solution B

Potassium (or sodium) hydroxide	5 ounces	125 grams
Water to	40 ounces	1000 ml

Immediately before use mix 4 parts of solution A with 1 part of solution B. Develop completely and for not less than two minutes.

Thoroughly rinse the print and immerse it in the following bleacher:

37 – BLEACHING SOLUTION

Potassium bichromate	175 grains	10 grams
Sulphuric acid, conc.	1 ounce	25 ml
Water	40 ounces	1000 ml

Dissolve the bichromate first in cold water, then slowly and carefully add the sulphuric acid, stirring constantly.

The print must remain in this bath until every trace of the developed image has disappeared. This usually takes about one minute.

Then wash the print for about a minute and treat in a 10 per cent solution of sodium sulphite until all yellowish tinge has gone. Wash again and redevelop in a normal print developer, for example one of the Formulae Nos. 12 to 16 on page 334.

The bleaching and clearing stages as well as the development can take place in normal white light. Before the print is placed in the second developer it must in fact be exposed sufficiently to white light so that every grain of silver bromide left behind after the primary development and bleaching is rendered developable. If a brown-black image colour is desired, a 2 per cent solution of sodium sulphide can be used, in which case no second exposure to light is necessary. (But see page 356.)

The quality and character of the paper naturally plays a large part in determining the type of result obtained. Ideal is

a smooth surface (preferably glossy) bromide paper of first quality (i.e. coated with a fairly rich normal emulsion).

CHROMOGENIC DEVELOPMENT

The term chromogenic is applied to substances which produce colours on oxidation. Chromogenic development is of course the principal way in which the colour images in colour films and prints are produced (page 366).

The same process can be employed for developing a bromide print to almost any single image colour.

The developing solution is made up from a basic colour developer to which is added the colour former or coupler. The universal colour print developer, Formula No. 28 on page 378, can be used as the basic colour developer, or Formula No. 38 below.

38 – FOCAL COLOUR DEVELOPER

DIEPPD*	35 grains	2 grams
Sodium carbonate, anh.	$1\frac{1}{4}$ ounces	30 grams
Sodium sulphite, anh.	18 grains	1 gram
Potassium bromide	18 grains	1 gram
Hydroxylamine hydrochloride	18 grains	1 gram
Water to	40 ounces	1000 ml

* Diethyl paraphenylene diamine bisulphite (Genochrome, Activol No. 1).

Immediately before use add 1 part of colour former to every 10 parts of developer solution. The colour formers are listed in Table XXIII and can be mixed in any desired proportion to vary the shade of colour obtained. The developer must be discarded after use.

Colour developers can be used on many papers, but not all. Some types, such as chloride papers, tend to be stained in the developer. Tests are also advisable with prints on plastic-coated papers to check the effect on the plastic coating and/or edges of the paper base. This applies also to the after-treatment and toning processes described in the following pages. (Plastic-coated papers may react unfavourably to the extended treatment times these processes require.) Where such papers are suitable, the final rinse times are again reduced accordingly, as described on page 350.

Formula and Colour	Ingredients	Amount (grams)	Solvent* (c.cm.)
39.—*Magenta*	p-nitrophenyl acetonitrile	0·5	100 A + 12 C
40.—*Yellow-Brown*	Cyanacetanilide	0·4	50 A + 50 C
41.—*Brown*	p-nitrophenyl acetonitrile	0·5	100 A + 12 C
	2:5 dichloro acetoacetanilide	0·5	
42.—*Yellow*	o-chloro acetoacetanilide	1	100 A
43.—*Yellow*	2:5- dichloro acetoacetanilide	1	100 A
44.—*Pale green*	Dichloro-orthocresol	0·9	100 A
45.—*Green*	2:4-dichloro-alphanaphthol	0·5	100 A
	2:5-dichloro acetoacetanilide	0·5	
46.—*Blue-green*	2:4 dichloro-alphanaphthol	1	100 A
47.—*Blue*	Alphanaphthol	0·7	100 A

*A = industrial methylated spirit (colourless) or pure alcohol
C = acetone.

After colour development rinse the print well and fix in a plain (not acid) fixer of 20 per cent hypo solution with 2 per cent anhydrous sodium sulphite added. Bisulphite or metabisulphite must not be used. If hardening is required, formalin can be added in the proportion of 40 ml per litre of fixer. The prints should not be washed longer than 30 to 45 minutes, or the brilliance of the colours may be impaired.

If a paper proves unsuitable for direct colour development, better results are usually obtained by processing the print to a normal black silver image – developing, fixing and washing in the usual way – and then bleaching with a ferricyanide-bromide bleacher such as Formula No. 33 on page 438. After bleaching the print is washed in water, immersed in a 2 per cent sodium sulphite solution for 1 minute and then redeveloped in the colour developer.

The colour of the print can be varied not only by the

choice of the colour former, but also by the following procedures:

(1) By auxiliary development in an ordinary MQ-developer. The print is placed in this after the colour development. By varying the time of treatment in the two developers, almost any degree of colour saturation is obtainable. For example, by this method a very deep and rich sepia can be produced by developing the print first in the colour developer containing couplers for orange-brown, and then the MQ-developer.

(2) By removing the silver image. If a perfectly pure colour is wanted, the silver image formed simultaneously with the dye image must be removed by Farmer's reducer (Formula No. 48 below). After all the black silver has disappeared, wash for about 15 minutes.

48 – FARMER'S REDUCER

Solution A		
Sodium thiosulphate (hypo), cryst.	1 ounce	25 grams
Sodium carbonate, anh.	88 grains	5 grams
Water to	40 ounces	1000 ml
Solution B		
Potassium ferricyanide	1 ounce	25 grams
Water to	10 ounces	250 ml
Working Solution		
Solution A		15 parts
Solution B		1 part
Water		15 parts

Make up the working solution immediately before use; this only keeps about 5–10 minutes.

Alternatively, bleach the print in the ferricyanide-bromide bleacher (No. 33 on page 438), followed by fixing in a 10 per cent solution of plain (not acid) hypo.

(3) By local removal of the colour. The dyes can be removed by the local application of 1 per cent hydrochloric acid. The silver image still remains in the print, and can be bleached and redeveloped to another colour in the manner described on page 445. By this method it is possible to produce two or more colours in the image, for instance developing a landscape print in a green-forming colour developer and removing the green in the sky areas, leaving only black silver.

The print is then bleached and redeveloped in a blue-forming developer, giving a blue sky.

An alternative way of local colour variation is to start with a black-and-white print and cover up all areas not to be coloured by a varnish such as a celluloid varnish. The print is then bleached and redeveloped in a colour-forming developer, after which the protective varnish can be removed with an alcoholic solvent. With care the process can be repeated to obtain several colours on one print.

TONING

At one time sepia to brown print images were very much in the fashion. These were obtained by toning, the classical procedure being to bleach the silver image – after normal processing – in a ferricyanide-bromide bleacher (again Formula No. 33 on page 438), followed by treatment in a 2 per cent solution of sodium sulphide. The main drawback of this method is that the sulphide solution has a very unpleasant smell of hydrogen sulphide (rotten eggs) which is also extremely harmful to all unexposed or undeveloped sensitive materials.

An odourless darkener for sulphide toning is the following:

49 – THIOCARBAMIDE BROWN TONER

Thiocarbamide, 5% sol.	4 ounces	200 ml
Potassium bromide, 10% sol.	16 ounces	400 ml
Sodium hydroxide, 10% sol.	1¼ ounces	30 ml
Water to	40 ounces	1000 ml

The colour obtained can be varied slightly by increasing the proportion of sodium hydroxide – up to about double the above amount.

The bleached and well washed print is treated in this solution until the image has gone fully brown.

Other sulphur and also selenium compounds without the objectionable hydrogen sulphide smell have also been suggested for sulphide (and selenide) toning. Generally it is more convenient to obtain warm brown tones during development by using a warm-tone developer (page 335) with a suitable paper.

Numerous other toning formulae have been proposed, depending mainly on converting the silver image either into

a differently coloured silver compound, or a double compound of a silver and another insoluble metallic salt. Metals whose compounds have been used for these processes include mercury, gold, iron, copper, uranium, nickel, lead, cadmium, cobalt and others. Most of these procedures are by now fairly obsolete, and the required chemicals not easily obtainable. If toned prints are desired, the chromogenic procedures described on page 444 are considerably more versatile, especially if used as toners proper for a normally processed bromide print, i.e. employed for redeveloping after bleaching in a ferricyanide-bromide bleacher.

One other toning method deserves mention, because it is even more versatile. This is dye toning. It can be used with an immense range of so-called basic dyes (basic in the chemical sense) as employed in the textile industry.

Dye toning depends on the fact that these dyes will not hold fast in gelatine, but are strongly adsorbed on so-called mordants. If the silver image is converted into such a mordant image which "takes" the dye, a dye image is produced as soon as the mordant image is immersed in a dye bath. The dye taken up is proportional to the density of the original silver image. Suitable mordants are the insoluble ferrocyanides, thiocyanates and halides of certain metals.

Various other dye toning systems have been described and patented, but the mordanting image is one of the simplest.

The print is first bleached in the mordanting bleacher – Formula No. 50 or 51. The second one gives somewhat purer colours because the mordanting image is nearly white, but it is liable to darken slightly on prolonged exposure to strong light.

50 – MORDANT BLEACHER

Solution A

Copper sulphate, cryst.	1 ounce	25 grams
Potassium citrate	4 ounces	100 grams
Glacial acetic acid	390 minims	20 ml
Water to	40 ounces	1000 ml

Solution B

Ammonium thiocyanate	$1\frac{1}{2}$ ounces	37 grams
Water to	10 ounces	250 ml

Potassium thiocyanate can be used in place of the ammonium salt. For use, slowly add one part of solution B to 4 parts of A, stirring the latter thoroughly. The solution must be clear.

The print is bleached until the image is greyish all over, washed in several changes of still (not running) water, and immersed in the dye bath (No. 52).

51 – MORDANT BLEACHER (TRAUBE)

Water	4 ounces	100 ml
Potassium iodide	175 grains	10 grams
Iodine	18 grains	1 gram
Water to	40 ounces	1000 ml

After dissolving the potassium iodide, make sure that all the iodine is fully dissolved before adding the rest of the water.

The image is bleached until it is completely white, rinsed in a 5 per cent solution of potassium metabisulphite to remove the yellow stain, washed again for 5 minutes, and dyed in the dye bath.

52 – DYE TONING BATH

Dye	35 grains	2 grams
Glacial acetic acid	190 minims	10 ml
Water to	40 ounces	1000 ml

XXIV – DYE TONING COLOURS

Colour	*Dyes*
Yellow	Auramine, Thioflavine T
Orange	Chrisoidin 3R
Brown	Chrisoidin brown
Red	Rhodamine 3G or 6G, Basic fuchsine, Safranine A, Neophosphine
Green	Victoria green, Malachite green, Methylene green
Blue	Methylene blue, Thionine blue
Blue-violet	Methyl violet, Benzyl violet, Crystal violet

It is also possible to apply the dye to selected areas with a brush, and to colour different parts of the image in different tones.

Higher concentration of dye decreases the contrast of the image, while a lower concentration increases the contrast but the image takes longer to dye. If the highlights tend to become stained, add more acetic acid to the bath. The print

is immersed in the bath until the dye image has the required strength, and then briefly rinsed in a 1 per cent acetic acid solution.

Suitable dyes and the colours obtained are given in Table XXIV on page 449. The dyes can also be mixed in any proportion.

The dyes sold for the Kodak Dye Transfer process can also be used, either by themselves or mixed together in different proportions.

RAPID ACCESS PROCESSING

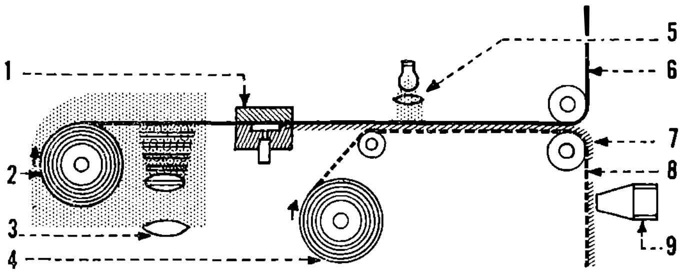
For all practical purposes motorized roller processors which pass papers (suitable for this process) through an activator and stabilizer in 10–15 seconds provide as rapid a processing system as we are ever likely to need.

Still faster processing is required only where the output of a printing darkroom is very high, in other words where processing has to keep in step with the production of exposed material, rather than where results are required instantly. Even there, it is more sensible to provide machinery for additional processing capacity; highly speeded up processing sequences are useful only in certain very specialized applications.

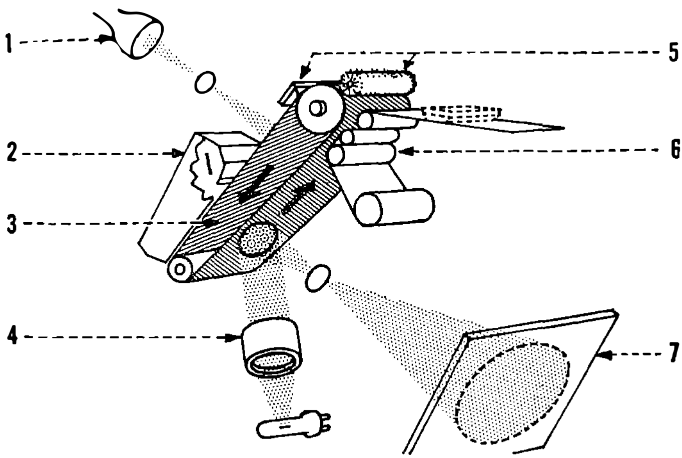
Rapid access techniques are mainly applied to negative processing, since this is more likely to be the bottleneck of a high-speed picture producing cycle. In most cases where the picture has to be available for viewing as soon as possible after exposure, the wet film is projected immediately it leaves the processing chamber or section of the rapid access system.

Sometimes print production may be designed as part of such a system, and there the exposing apparatus (a special camera), the processing and the positive production become a single unit.

One example is the arrangement shown on page 451. Here a monobath (combined developer and fixer) is applied to the film surface as a viscous solution as soon as the film leaves the camera. A little further on along the film path, once the negative image has developed, the positive material is sandwiched face to face with the negative emulsion, so that the monobath developer is between them. The positive material, like the negative film, is fed from a continuous roll.



The film coming out of the camera is developed by a viscous developing solution, sandwiched into contact with the positive material, the latter exposed through the meanwhile developed negative and developed by the same viscous solution sandwiched between the two layers. On separation from the negative, the positive is immediately ready for viewing. 1, processing solution applicator; 2, film supply in camera; 3, camera lens; 4, positive paper roll; 5, printing light; 6, negative film; 7, processing solution layer; 8, positive material; 9, viewer.



Sophisticated rapid access systems may not use chemical processing at all, and show the image before it is processed. This xerographic arrangement uses the electro-photographic powder image on a flexible selenium belt for viewing. 1, exposing system; 2, powder development; 3, selenium belt; 4, projection light; 5, electric charging and cleaning stations of the selenium belt; 6, image transfer on paper and fixing (if required); 7, screen showing the image formed on the selenium surface by the powder development. This kind of system is however already appreciably removed from orthodox photographic printing.

A lamp behind the negative film now contact-prints the developed negative image onto the positive paper, while the monobath solution layer between the two immediately develops the positive image as well. The negative and positive strips are then separated, the monobath solution washed off by a spray, and the picture can immediately be examined. The negative and positive strips may run through further drying stages before being spooled up.

Rapid access systems are specially feasible with dry processes which do not use conventional light-sensitive silver halides at all, but rely on the effect of light on the conductivity of semi-conductor surfaces. (An example is electrophotography – page 507).

An almost simultaneous production of a negative and positive takes place also in transfer-diffusion processes (page 499). These are widely used in photo-copying systems, where the negative is a necessary intermediate stage in the process, but is usually discarded afterwards. The Polaroid Land camera applies the same principle to general photography (in black-and-white and in colour), but the pictures are here contact prints produced in the camera.

ENLARGING WET NEGATIVES

Where rapid production of a picture is important under more orthodox conditions, e.g. in race-finish or sometimes in newspaper photography, negatives can be enlarged while still wet, as soon as they leave the rinsing stage of their own processing sequence. The only point to note is that all excess water, including drops, must be removed from the surface.

Also, the emulsion surface should not touch any part of the negative carrier of the enlarger (except at the edges) as it is easily damaged. This was no problem when glass negatives were more widely used than they are now; the plate could simply be dropped into the rebate of a plate carrier of the enlarger. The simplest way of handling wet films in the enlarger is to sandwich them between glass plates, with a layer of glycerine between both film/glass surfaces. Special negative carriers exist to facilitate this sandwiching without spilling drops of glycerine into the enlarger itself. The glycerine layer also helps to hide scratches and other minor flaws in the negative. Glassless sheet film carriers with tension clips (page 160) are also suitable for wet films.

DRY PROCESSING

Completely dry chemical processing, i.e. not requiring solutions at all, has obvious advantages not only as regards speed, but also by eliminating all handling of chemicals. Various schemes have been proposed, mainly in patents.

(1) A direct step forward from two-bath roller processing with activator and stabilizer is to incorporate not only the developing agent, but all the other chemicals for development and stabilization in the paper emulsion. When the exposed paper passes through a roller processor, the latter only has to apply water to the emulsion surface to start the processing reactions. Development and stabilization could be prevented from interfering with each other by making the development speed appreciably higher than the stabilization rate. The main difficulty would however lie in the manufacture of such a material, since the stabilizer chemicals must be prevented from interacting with the unexposed silver halide while the emulsion is still in its liquid state.

(2) To dispense with even a water bath in the processor, the paper with incorporated chemicals (developing agent plus alkali) can be made to pass over a heated roller. This drives the normally present moisture from the paper base into the emulsion where it initiates development. On leaving the processor, the print carries a visible image, which is of course not stabilized and not permanent. This may be acceptable where an image is required exclusively for immediate inspection (e.g. oscillograph records), but not for subsequent filing or reference.

(3) A third way already used in some materials and proposed for certain others is micro-encapsulation. Here the developing solution is contained in microscopic colloid binder capsules dispersed in the gelatine layer of the material. The capsules also contain a so-called blowing agent, an organic nitrogen compound which decomposes on heating to give free nitrogen gas. When the exposed paper containing such micro-encapsulated developer passes over a heated roller, the nitrogen gas liberated bursts the capsules, releasing the developer solution which develops the exposed silver halide on the spot. Immediate evaporation gives a completely dry print when the paper leaves the processor.

There are several ways of incorporating both development and stabilisation into such a system.

Different blowing agents can be made to decompose at different temperatures. In this way it becomes possible to incorporate both developer and stabilizer in the same emulsion. The developer micro-capsules contain a low-temperature blowing agent which releases the developer when the paper passes over a moderately warm roller. The stabilizer capsules at this stage remain unaffected, but in turn liberate their chemicals when the paper passes over a second, hotter roller to complete the processing sequence.

Alternatively, the micro capsules can contain a monobath-type stabiliser. Here the development and stabilising actions are appropriately balanced so that the former is completed before the latter gets under way. Since the whole processing time is only of the order of about 10 seconds, such a balance must be fairly delicate. The development and stabilisation rates may change differently with temperature; by varying the exposure and the temperature of the heated rollers the paper can then be made to yield prints of different contrast. Enlarging papers based on this principle are used for rapid and simple proofing of negatives, for the re-enlargement of microfilms etc. With its emphasis on rapid and simple processing, this procedure generally makes some compromises in print quality and does not match the tone range, image colour and brilliance of prints produced by conventional wet processing methods.

In another system suggested for dry processing, also based on micro-encapsulation, the chemicals released in the emulsion by heat convert the normal latent image into one which blackens readily on exposure to light, and destroy the ability of any remaining silver halide to form more latent images. The final step of this process is exposure of the "heat stabilised" image to strong white light; the secondary latent image then produces the final silver picture. This heat processing takes about 2–4 seconds.

Yet another development of micro-encapsulation materials involves colour coupling development to form dye images. This is used in certain dry document copying processes (page 509).

Retouching, Trimming, Mounting

All the tiny flaws in the negative such as scratches, adhering dust particles and pinholes, are reproduced in the print. The greater the degree of enlargement the more obvious such defects become.

Since in practice miniature negatives have to be enlarged considerably to obtain a print of useful size, retouching assumes an importance in amateur photography that it did not formerly have. As retouching a miniature negative is a thankless task at best, retouching is largely confined to work on the positive image.

SCRATCHED NEGATIVES

Scratches in the negative, including those on the back of the film, show up on the print because the scratch scatters light and thus appears as a shadow when the negative is viewed against a bright light source. Such scratches show up most strongly in a condenser enlarger with point source lighting and they virtually disappear in an enlarger using fully diffused illumination. While there is no remedy for scratches which have actually removed emulsion (and with it parts of the silver image) from the film – apart from spotting of the negative (page 458) – superficial scratches may be subdued by sandwiching the negative in oil between two sheets of glass. Any kind of fine oil may be used for the purpose (salad oil, typewriter oil and castor oil are all quite satisfactory), and other fluids such as glycerine, carbon tetrachloride may be substituted for oil if desired.

When making the sandwich, no air bubbles must be allowed to form. The simplest way of avoiding them is to place a few drops of the oil on a glass sheet, and then lower the negative slowly onto the liquid so that the latter gradually runs over a fair area of the image. Without pressing down, which might result in the film springing back when released and causing air bubbles, a similar quantity of oil is placed on the top of the film, and a second glass plate

lowered gently on to it. Careful pressure may now be applied, when all the oil will spread nearly over both sides of the film without any bubbles.

A "wet" negative carrier (see page 452) is most suitable here, since it prevents the oil or other liquid from soiling any other part of the apparatus. Otherwise all oil must be cleaned away carefully afterwards with petrol – both from the negative and from all parts of the enlarger it has reached.

A simpler method is to treat the negative with a so-called scratch remover which renders the scratches invisible. Such removers are really varnishes or lacquers which in their dry state have practically the same refractive index as gelatine. So when they fill up a scratch in the gelatine, its scattering effect disappears and the scratch itself becomes invisible in the projected image. The scratch remover is applied in the same way as a negative varnish, i.e. poured over the dry clean negative and the excess allowed to drain away, followed by drying of the film in a dust-free atmosphere. Not only does this treatment deal with scratches, but it also protects the negative against further damage.

If dirt has got into a scratch, the negative must be cleaned before the varnish is applied. This cleaning operation needs great care: place the negative in water until the gelatine is well swollen, then rub very gently but thoroughly with a swab of clean fluffless linen or a camel hair brush. Then carefully dry, and treat with the varnish. If negatives so treated are later scratched, the scratches frequently do not penetrate beyond the protective coat, and can easily be dealt with by a second treatment with the varnish.

SPOTTING PRINTS

The essential afterwork on enlargements is the removal of both white and black spots on the print resulting from blemishes in the negative or dust during enlarging. Dust on the negative in the enlarger, as well as scratches and dust on the glass plates of a glass negative carrier are the most obvious causes of white marks in the enlargement requiring removal. At this point it is worth noting that prevention is better than cure – the biggest argument in favour of glassless negative carriers, since glass carriers are notoriously difficult to keep clean all the time.

White spots in the print may be literally spots, or they may

be short hair lines which are the shadows of dust particles, minute fibres, etc. If these have settled on the negative during enlarging, they will be bigger the higher the magnification. Dust settling on the paper during exposure is usually fine enough not to show up in the print. (Also, dust is less likely to collect on the enlarging paper during the exposure.)

White spots are most easily removed by water colour applied with a very fine camel hair brush. Successful spotting depends largely on having the brush neither too wet – when it deposits blobs of colour on the print surface – nor too dry, when it does not yield up its colour easily.

The proper technique is to wet the brush and then stroke it half dry on a piece of clean paper. Next take up some colour, preferably from a palette or the cake of dry water colour, and turn the brush on a piece of white paper. This at the same time helps to get a fine point, and also shows the strength of colour in the brush. Then just touch the spot on the print with the tip of the brush – this should be sufficient to fill it in if the colour was of the right depth. It is best to start spotting in the darker areas and work gradually to the lighter ones as the paint released by the brush gets weaker.

If the spot is comparatively large, repeated applications may be necessary, but the colour should be applied in small dabs rather than painted on bodily. (It is difficult to get an even coverage that way with water colour.) Too much colour can be removed with a piece of moist cotton wool. It is however advisable to wait until that print area is fully dry again before repeating the spotting procedure. For glossy papers a little gum may be added to the spotting colour to preserve the surface sheen.

Alternatively, retouching dye may be used. Unlike water colour, this is a clear solution, and not a suspension of pigment. This is equally suitable for glossy as for semi-matt or matt surfaces. Here the dye should be dilute in the brush, but the latter still semi-dry, and it is applied repeatedly to the spot until the latter disappears in its surroundings. Too much dye is more difficult to remove, and requires resoaking the print in water and drying it again.

Semi-matt papers can sometimes also be spotted with a soft pointed pencil. The sheen of these pencil marks is however visible on fully matt papers. Also, pencil spotting rubs off easily.

BLACK SPOTS

These can be removed from semi-matt or matt surfaced prints by careful scraping with a very sharp razor blade or a retouching knife. The secret here is to shave off the emulsion surface – and with it the image – with very fine strokes. Larger spots can be dealt with by a cross-hatching movement, but very dark spots are difficult to remove without digging through the emulsion layer into the plastic coating or the paper surface itself.

Knifing in this way always shows up on the print surface, especially on a glossy one. If too much emulsion has been removed, and the spot becomes too light, it can be filled in again by spotting with water colour as described above.

A better way of getting rid of dark spots is with the iodine reducer (formula No. 35 on page 441). This completely bleaches out the spot when applied with a fine brush; the print is then refixed and washed, and the light spot remaining filled in with water colour or dye.

Dark spots are generally due to scratches, pin holes, air bells or other blemishes on the negative. Often it is better to fill in these spots with water colour or spotting dye on the negative itself, and tone the spot into its surrounding area by applying spotting colour to the print.

RETOUCHING COLOUR PRINTS

Light spots on colour prints can be dealt with in much the same way as on black-and-white prints, using transparent coloured dyes to match the surroundings of the spot to be filled in. Sometimes the spot on the print may be brightly coloured in a dark toned area, due possibly to faults in one of the image layers only.

Generally it is easier to work with three spotting colours only – yellow, magenta and cyan – and apply these in turn to build up the necessary colour and density to fill in the spot. Spotting colour prints is thus a lengthier process and requires more patience than with monochrome pictures.

Knifing is out of question on a colour print, since this removes the component colour images successively as scraping proceeds, and not simultaneously. If dark spots are due to blemishes in the colour negative, it is best to fill them in on the latter, and touch up the resulting light spots on the print.

ADVANCED RETOUCHING

Apart from attempts to remove the effects of spots and scratches in the negatives, dust etc. no further retouching should be necessary in a print. The "artistic" retouching commonly used in commercial portraiture should be left to those who have to please their customers. (And portrait retouching is in any case a highly skilled craft requiring considerable experience.) To change the character of the image will only destroy its photographic quality. The same is true of the production of clouds by graphite rubbed over the print and removed from the sky with an eraser. If clouds have to be added, it is much more satisfactory to print them in as described on page 481.

While imaginative commercial photography – especially in fields like advertising – frequently calls for effects which are far from straightforward photography, these are generally obtained during the production of the negative or of the print, and very rarely on the finished print itself. At the same time it must be admitted that views about the admissibility of extensive non-photographic afterwork on prints are controversial, personal – and changing. Handworked prints are much less acceptable than they used to be, possibly because only really enthusiastic amateurs can spare the time for it. Retouching of this kind is hardly ever economical for the professional photographer who may have to produce prints by the hundred. (In negative retouching at least the work has to be done once only, and not on every print.)

An exception is the air brush of the commercial photographer or, more likely, of the art department of an advertising agency or engraving firm. This essentially non-photographic process is confined to the production of graphic distinct from photographic – effects. Air brushing is used – as almost exclusively on pictures which are to be reproduced in print. Where an enlargement is the end product on its own, air brush work is too prominent to be acceptable. On subsequent rephotographing, however, the pigment and photographic image areas blend together to yield the desired improvement in the reproduction.

Air brushing consists of spraying an opaque pigment on to the print surface. To darken image areas the pigment is mixed to a dark shade; to lighten them to a lighter shade or even white. Since the pigment is opaque, it obscures detail

underneath; this property is widely used to get rid of disturbing background detail in a picture without the more obvious cut-out effect of blocking out in the negative. Air brushing can also be used to make individual image portions clearer against their background, to put in highlights etc.

Since it is difficult in air brushing to keep accurately to sharp outlines, areas which are not intended to receive any pigment are usually protected by cut-out masks. These are traced on to transparent or translucent plastic sheets which are laid over the portions to be protected. During an extensive air brushing job a number of separate masking stages may be necessary. For the simplest type of air brushing, for instance to subdue a background, the main subject only is traced out as a mask, and the latter placed in position while spraying all round it.

If the air brush work is to be temporary only, and should not spoil the print itself, the spraying can be carried out on a clear plastic sheet or overlay fastened over the print itself.

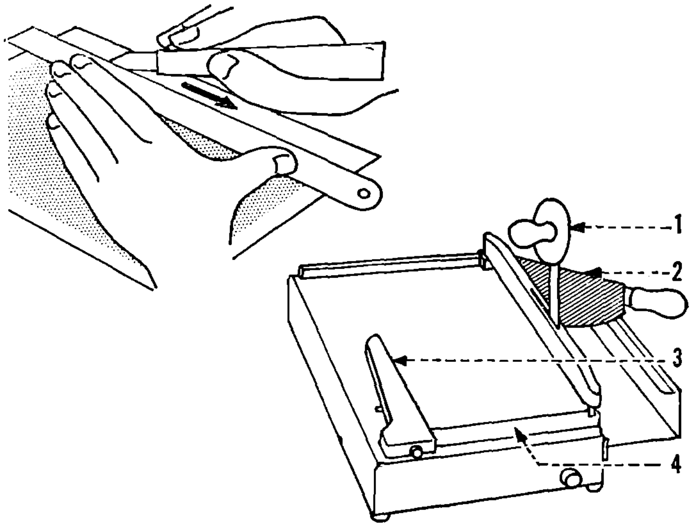
TRIMMING

An enlargement only becomes a picture in the true sense of the word when it has been trimmed up and mounted. The simplest way of trimming is to cut along the print edges – for instance to make a white margin uniform – with a trimming knife or even an old safety razor blade against a straight steel or brass ruler. A piece of plate glass or stiff cardboard should be used as a support underneath the print during the trimming operation. (Glass however rapidly blunts the trimming knife.)

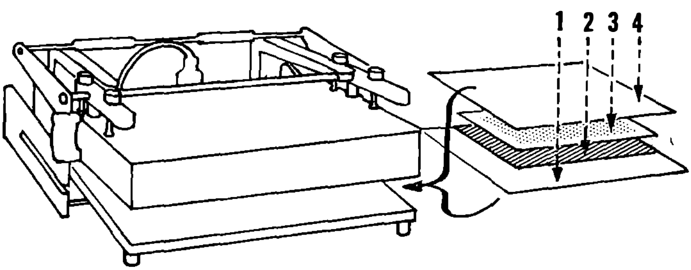
If a print is to "bleed" – i.e. have no white border at all – the latter is simply cut off all round the picture. This is often more convenient than making the enlargement without borders in the first place, since most masking frames (page 255) necessarily leave a white border where the frame and its masking strips hold the paper down. The trimmed edges must however be truly at right angles to each other all round.

Most convenient for trimming are the various types of guillotine and desk trimmer. Usually these have a straight-edge along one side to ensure that successive cuts are truly squared up, and to permit trimming a print to exactly predetermined dimensions.

During trimming the print should be held down firmly near



The simplest way to trim a print is to place it on a card surface and cut off the edges along a ruler with a sharp knife (*left*). More convenient is a trimmer, for example a guillotine type (*right*). Elaborate models of this have various guides and aids for accurate and rapid trimming. 1, clamping lever to hold print securely; 2, trimming knife; 3, squaring guide; 4, inch and/or centimetre scale.



A dry mounting press (page 463) sandwiches the print and mount between two heated plates to melt the dry mounting tissue and weld the print to the mount. The arrangement of the items when inserted into the press is: 1, mount; 2, dry mounting tissue; 3, print; 4, covering sheet to protect the print surface.

the cutting edge to ensure a clean straight cut. Some trimmers incorporate a clamping arrangement which automatically holds down the print edge being trimmed. Present-day guillotine trimmers often incorporate a guard enclosing the knife to protect the user against injury. Such protection is obligatory in professional darkrooms.

Guillotine trimmers are available with cutting knives of various lengths up to several feet. For most amateur and professional work a 35–50 cm cut is usually adequate. Some trimmers give a so-called deckle-edge cut instead of a straight one. This tries to simulate – though rather poorly – the torn edge of hand-made papers. Deckle-edged prints are largely a matter of taste and fashion; they are rarely used in straightforward professional work.

MOUNTING

For exhibition and display purposes prints are usually mounted on stiff boards which set off the picture by a broad light border, and also protect the edges of the print itself against damage.

The reaction to mounting media of plastic-coated papers is different from that of plain papers. The exact effect depends on the plastic used and on its surface texture; thus some plastic papers cannot be mounted with wet mounting pastes which rely in their action on the adhesive entering the paper pores. Preliminary tests are therefore advisable. The manufacturer's instructions also give further details.

Dry mounting with tissue or lacquer, provided this has a low enough melting point not to damage the plastic, is suitable for plastic-coated papers, as is mounting with self-adhesive films (page 464).

A simple way of mounting a print is with a suitable mounting paste. This must be free from acid, since the presence of the latter tends to cause deterioration of the image in a comparatively short time. The paste is applied over the back of the previously dampened print, and the latter then placed on the mount in the required position and kept under pressure for an hour or two until the paste has dried. When pasting down, a pair of light pencil lines can indicate the position the print should occupy; these can be readily rubbed off later if they remain visible.

If the mounting board is not very thick, it is advisable to

stick another sheet of paper on the back immediately after the print itself is mounted. This counteracts the tendency of the mount to bend inwards owing to contraction of the print as it dries on the mount.

Various rubber and latex mountants are also available. Here again it is important to use a type recommended for photographic purposes, as ordinary commercial rubber solutions may contain chemicals which can attack the image in time. The plastic layer of plastic-coated papers effectively insulates the image from possibly harmful chemicals in mountants. But certain rubber or latex mountants may again not stick too well to the plastic surface.

Mounting with rubber solution is easier than with paste, for the solution is simply rubbed over the back of the print and over the area it is to occupy on the mount. The two are left to dry for a short time, and then brought into contact. The print then adheres immediately and firmly to the mount – hence accurate location is essential before contacting the two surfaces spread with the rubber mountant. Any excess rubber or latex solution around the print can then be removed by simply rubbing.

As rubber solution mounting involves no wetting of the print with water, no shrinkage occurs on drying. Hence no backing is necessary for the mount to counteract curling. Rubber mounting is not, however, absolutely permanent, for the adhesive eventually deteriorates (generally within a few years) and the print then peels off its mount.

For more temporary mounting double-sided self-adhesive cellulose tape is useful. A length of this may be applied to the top edge of the print, or shorter pieces to the four corners. The protective backing of the tape is then stripped off, and the print placed in position on the mount.

The most satisfactory permanent mounting process uses dry-mounting tissue. This is thin tissue impregnated with a low-melting resin like shellac. The heat to melt it may be provided either by a flat iron or a heated dry-mounting press. The tissue is first tacked to the back of the print (to keep it in place) by pressing a hot iron against it in a few spots while the two are held in contact. Both the print and the tissue may then be trimmed together to the required size. They are next placed in the required position on the mount, covered with a piece of white paper to protect the print surface, and

ironed down with the flat iron which should be at about 100°C. With plastic-coated papers the dry mounting temperature should generally not be above about 80°C, as it may otherwise lead to disfiguring of the plastic surface. Dry mounting tissues of suitably lower melting point are preferable.

The correct temperature is fairly important for successful dry mounting. If the iron is too hot, the tissue sticks to the mount but not to the print; if the iron is too cool, the tissue may stick to the print, but not to the mount. For this reason, and also for greater convenience, professional studios and photo departments almost invariably mount their prints with the aid of a dry mounting press. This consists essentially of two heated platens of appropriate size, with thermostatic heat control. The platens may be up to 40×50 cm or 16×20 inches large.

The print, correctly positioned on its mount, is placed between the platens under pressure for a few minutes. Prints larger than the platen size can usually be mounted piecemeal by successive application of heat and pressure to different areas of the print.

Low-melting varnishes are also marketed to eliminate the need for dry mounting tissue. Here the varnish or dry mounting solution is painted over the back of the print, allowed to dry fully, and the print then located on the mount and placed in the dry mounting press.

Self-adhesive sheeting is another effective and convenient way of mounting most prints, including plastic-coated ones. The mounting medium is a very thin tissue coated on both sides with a self-adhesive layer, and protected on one side with a silicone treated backing paper.

To mount a print, peel off from its roll a piece of the self-adhesive paper large enough to cover the back of the whole print and to protrude slightly beyond its margins. Place this sheeting with the adhesive side downwards onto the back of the print (which must be completely free from dust, grit or other foreign matter) and rub well down all over the back of the print. Lay the print on a completely smooth but firm surface (e.g. a sheet of clean cardboard) for the purpose. Again avoid any grit between the edge of the print and the supporting surface, otherwise this will cause marks.

The self-adhesive material is attached to the back of the

print before the latter is finally trimmed. Then trim the print together with its adhesive backing. Next carefully peel off the silicone backing paper, leaving the self-adhesive layer on the back of the print, and exposing the second adhesive surface.

Finally lay down the print carefully on the mount and smooth down all over.

This last step needs some care, as the print is difficult to lift once it has been wrongly located on the mount. The self-adhesive medium is usually a latex type compound; in theory it is subject to the same long-term deterioration as rubber solution (over a period of years). In practice the adhesive formulations are however more permanent than the normal office type of rubber solution.

Special Processes and Techniques

MONOCHROME ENLARGEMENTS FROM COLOUR

Reversal transparencies made on the various types of colour film can also produce exceedingly satisfactory prints in monochrome, since their images are of comparatively fine grain. The degree of enlargement obtainable is limited mainly by the definition of the camera lens and the emulsion of the original film.

To produce a monochrome enlargement from a colour transparency, three methods are possible:

(a) An enlarged negative may be made from the transparency, and prints made from it. This method is the most convenient where a considerable number of prints is required of each picture.

(b) A contact negative is printed from a transparency, and later enlarged in the ordinary way.

(c) The transparency is enlarged directly on a bromide paper, and the latter processed by reversal (page 442). This is the simplest method but is suitable only for comparatively soft transparencies since it becomes especially difficult here to accommodate the great brightness range of an average transparency within the exposure range of the paper. (This applies to some extent also to the other two methods.)

Where an intermediate negative is made, the colour sensitivity of the negative material is important. Since the colour transparency reproduces in its image more or less the original colours of the subject, only a panchromatic film is really suitable for the intermediate monochrome negative. The film selected should be a comparatively soft-working low-speed material. During the exposure it is particularly important to keep all light from the enlarger, except that passing through the lens, from reaching the film being exposed. That may involve wrapping a dark cloth round the lamp-

house before the actual exposure. Since the latter is likely to be of short duration, no serious overheating of the enlarger should arise.

A bromide paper used for method (c) should also be panchromatic (see page 76).

If the colour transparency is a miniature-format one and the enlarger can take bigger format negatives, it is usually most convenient to produce the intermediate negative by enlarging. Bigger size transparencies are best contact-printed (page 477) to produce the intermediate negative; the same applies if the enlarger will not take bigger negative formats and the original transparency is a 35 mm one. For contact printing really even and firm pressure in the printing frame or box is essential to keep the colour transparency and the negative material in close contact during the exposure. Otherwise the negative may be slightly unsharp in places, which is all the more noticeable when it is enlarged.

A further possibility is to prepare an intermediate enlarged paper negative, and make contact prints from it (page 476).

Colour negatives can of course be enlarged directly on ordinary bromide paper to give black-and-white prints. Here again a panchromatic paper is preferable for more natural tone reproduction. With orange-tinted masked colour negatives (page 76) the exposures on ordinary bromide paper may be inconveniently long, since bromide paper is virtually insensitive to orange and red light. This also leads to a very pale rendering of image tones corresponding to blues and greens in the original subject while reds come out very dark in the print.

GIANT ENLARGEMENTS AND PHOTO MURALS

Photo murals are photographic enlargements of extreme size used for decorative or publicity purposes, often to cover the whole wall space which may in extreme cases extend to 10 square metres or over 100 square feet. They may consist of single pictures or combinations of enlargements to produce a suitable composition.

Really giant enlargements are rarely possible with the average type of vertical enlarger, due to its restricted range of magnification. (The final enlargement of a single photo mural can reach as much as 100 diameters!) While big en-

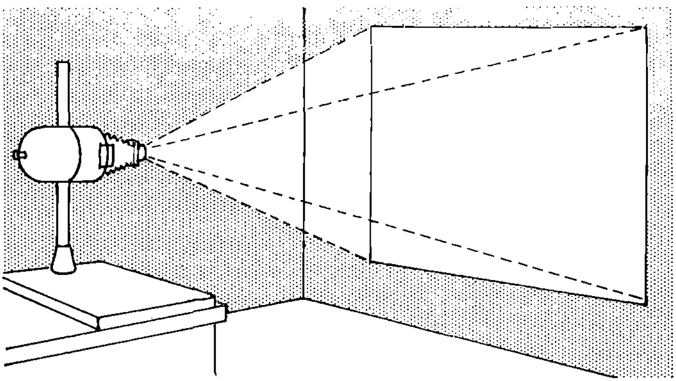
largements are possible by swinging the lamphouse of a vertical enlarger round on its column and placing the paper on the floor (page 165), a horizontal enlarger is often more useful, though it may need special facilities for this type of work. Thus it must permit horizontal and vertical movement of the negative to facilitate accurate centering. Also, such an enlarger needs a powerful light source (for example a mercury vapour lamp) to permit reasonable exposure times at such magnifications. Focusing has to be done very carefully, as the slightest blur shows unpleasantly when greatly enlarged. It is a good idea to place a small feather in a negative carrier, as the finest lines of a feather can be focused much more conveniently than any line in the negative. Once the feather is sharp, the negative is put in its place.

The real limit to the size of an enlargement that can be produced in a single exposure is however the maximum width in which photographic paper is manufactured. This is nowadays about 140 cm (55 inches). While paper can be coated in very long lengths (roll paper is available in rolls up to 30 metres or 100 feet) a limit is also placed on the length of the paper that can be handled by the size of the bath in which the enlargements have to be processed. It has been found that anything larger than $1 \cdot 4 \times 3$ metres or $4\frac{1}{4} \times 10$ feet is too difficult to handle satisfactorily.

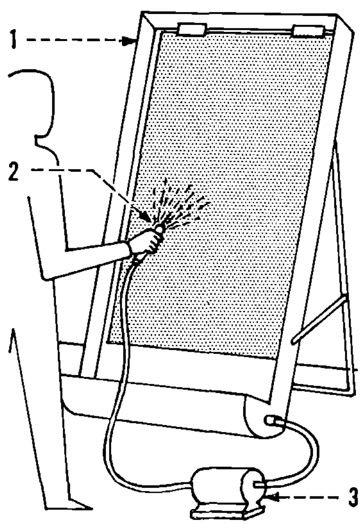
Photo murals are usually prepared by specialist firms which have the necessary equipment. They have their own methods which may vary widely, but all the usual rules must still be observed which govern the choice of negative materials (page 68), developer (page 58), printing technique, etc., always keeping in mind the greatly increased scale of operations. The negative should preferably be on the thin side and have fine grain to allow large-scale magnification. Graininess is however not too important a consideration if the mural is not likely to be viewed at very close range.

In view of the limitations of paper size, big murals are almost invariably made in sections. These sectional prints, which must match very precisely in magnification as well as in density, are then assembled together on the wall they are to occupy, in an operation reminiscent of wall papering.

Where a single negative has to be printed in sections it is usually advisable to recopy the negative in sections first on to a larger-format film. Each section should have the biggest



For really big enlargements the enlarger can sometimes be turned sideways on its column to project on to giant sheets of printing paper pinned up on the wall.



One way of processing giant prints is in a big upright dish 1, fitted with a receiving tray at the bottom. The processing solution is applied as a spray 2, being pumped from the receiving tray by a small pump 3.

Large-size models of drum and roller processors (page 232, 372) also exist.

format that the enlarger employed will take. These negatives must of course be exposed and processed under identical conditions to ensure accurate matching. If the original negative is already a large-format one, it may be sufficient to centre different sections of it in the masked-down negative carrier of the enlarger, and use a shorter focus lens to achieve the necessary magnification for each print section.

The prints themselves are best made on a rough surface paper of the largest dimensions which the available processing equipment can handle. Glossy or strongly shiny surfaced papers are not recommended, because the reflections from the surface can be disturbing when viewing the completed mural. Also a glossy surface shows up the minutest unevenness in the wall or other support for the mural.

Photo murals of line originals, such as reproductions of old drawings, charts etc. – can also be made on tinted paper or canvas (page 111).

GIANT PRINT PROCESSING

The development of larger sheets of paper is a major problem. The ideal method would be an automatic developing machine capable of taking paper of sufficient width. It is possible to develop sheets in large trays which take the prints once folded, or to see-saw the paper through a dish of the required width. The ends of the paper strip must for this purpose be fixed to battens to facilitate handling.

Giant versions of drum paper processors of the kind described on page 372 for colour prints may take sheet sizes up to 125 × 250 cm or 50 × 100 inches. Models even exist to process paper rolls up to 140 cm or 53 inches wide and 10 metres or 33 feet long, intended exclusively for firms specialising in photo mural production.

Another method is to place the print in a large upright dish (made for this purpose up to 1·2 × 2 metres or 4 × 6 feet large) and spray on the developer, fixer etc. in turn.

One material especially suitable for photo murals is an enlarging paper emulsion coated on canvas support (see also page 109). This is available in even greater widths than the limit for paper rolls, and does not need dishes of quite the same extreme size. The print can be folded over on itself several times in the developer without harm. With this material much bigger photo murals can be made in one

single exposure, and the canvas processed in a bathtub-size trough into which the developer, stop bath, fixer etc., are run in and drained off in turn. For drying such a giant canvas must however be tensioned on a frame – unless the material is pasted on the wall while still in a half-damp condition. The canvas support also is more resistant to wear than a paper base.

MURAL MOUNTING

The mounting of a mural on paper is best carried out by spreading paste uniformly over the back of the dried print, just as is done by expert paper hangers. The print is then placed in position on the wall and brushed vigorously towards the edges with a dry brush or duster. At the joint the edge is rolled with a paper hanger's roller or squeegee. If the print has been properly pasted and applied there should be no separation from the wall, and joints – matched up carefully – should be invisible.

Individual enlargements of a large mural can also be made somewhat overlapping. When the sections of the mural are pasted down, they are overlapped in the same way. Then, while the paper is still damp on the wall, the joints can be trimmed with a sharp knife and straight edge.

The knife must cut through both thicknesses of the overlapping paper. After this the waste edge strip is peeled off the top, the edge raised and the corresponding edge strip of the other section removed from underneath. The two edges are then smoothed down and should butt together accurately. This trimming operation is best done when the mounted paper is nearly but not quite dry, to reduce the risk of gaps through subsequent shrinkage. To prevent mis-matching due to shrinkage the paper for each section must also be cut off the roll in the same way.

Another method for matching edges where the separate sections overlap, is to thin down the overlapping strips from the back of the paper by sandpapering. If these thin edges of the paper are pasted over each other, they are prevented from peeling off along the joints without showing a double thickness of paper. To make the paper stay on the wall, thin muslin can be applied to the wall first. The sections of the photographic paper are then wetted and pasted to the muslin surface after the latter has thoroughly dried.

COMPOSITION MURALS

Where murals are made as composition prints from several images, more preliminary planning is needed. This starts with a rough pencil sketch which is the basis for a paste-up model made from the required portions of the various photographs which are to supply the mural. This rough model on a small scale – the single pictorial elements of which will not necessarily fit and join yet – serves merely to give an idea of the actual comparative scale to be used, to decide on the final composition and to check up on the massing and harmonizing of the subject as a whole.

The next stage is an improvised photographic model which is studied to decide how the mural is to be split up, where the joints are to appear, whether sections are to be vertical or horizontal etc. This also provides the plan which decides the sequence of actual copying and enlarging. The tone values in this model and its photographic quality in general should be high, as it is the starting point of the actual photographic work.

The photographic model is now copied on to one or more negatives, depending on the size of the model and the final size of the mural. The negatives are then scored on the margin of the film to mark the individual pieces or sections of the mural. These scorings control the accuracy of the enlarging and also act as guides for mounting the enlargements.

Once the mural is mounted, it also needs suitable illumination to look effective. This is important since photo murals are frequently used to represent outdoor views on walls of rooms, and the brightness of the mural must be sufficiently above the brightness level of the room to look like a convincing outdoor view. If the illumination is really powerful (for instance by banks of floodlamps hidden behind screens around the edges of the mural) the apparent brightness range of the giant image is also increased. This is partly because (a) the high intensity of illumination tends to bring out more shadow detail, and (b) a great difference in brightness between the illuminated mural and its surroundings simulates the impression of a brightness range associated with outdoor scenes. This is particularly effective with giant colour prints mounted on a wall and suitably illuminated.

TRANSPARENCIES AND DUPLICATE NEGATIVES

The production of positive transparencies and duplicate negatives has already been touched on briefly in the discussion of tone separation procedures (page 410). Here the process will be explained somewhat more fully. A positive transparency is merely a positive image on a transparent support, which is viewed or projected by transmitted light.

Transparencies from 5 × 5 up to 8.2 × 10 cm (2 × 2 to 3½ × 4 inches) can be made on positive films and low speed negative materials available in various sheet sizes. Such transparencies are then glass bound to form lantern slides for projection. Copying materials and slow negative films also exist as perforated 35 mm stock for producing either continuous film strips or single transparencies for mounting in standard 5 × 5 cm slide mounts.

The selection of the best material depends largely on the type of transparency required. High-contrast process films and positive films are useful for transparencies of diagrams and other line originals. A medium-contrast film is best for making transparencies from normal negatives, and panchromatic materials are required for black-and-white transparencies from colour originals. For black-and-white work a blue sensitive film is however adequate and more convenient to handle in the darkroom by bright red lighting.

The speed of process and positive materials varies widely from bromide paper sensitivity upwards. Exposures therefore have to be determined by preliminary tests.

In general the selection of film gradation to match negative gradation follows similar principles to the selection of a printing paper of the correct contrast grade, but is much more flexible. Thus for soft negatives we shall normally need a contrasty positive film and for high contrast negatives a soft working film. But within these limits the contrast of the transparency image can be increased by a high contrast developer or – at the other end of the scale – reduced by a low contrast formula or by increasing the exposure and reducing the development time.

Transparencies are normally printed by projection in an enlarger, but the magnification is necessarily much lower. When making transparencies on a 35 mm film it may even be necessary to reduce the image scale.

While aftertreatment of papers by the ordinary intensifiers

and reducers is rarely satisfactory, and seldom improves the image quality, transparencies may frequently be saved or even improved by such treatment. (Full information on intensification and reduction will be found in a book in this series dealing with negative technique.)

If a positive transparency is printed on a second sheet of sensitive material, the result is a duplicate negative. In addition to their use in tone separation processes, duplicate negatives are frequently convenient for other processes as well. For instance where a giant enlargement is to be made, the exposure time with a small negative would be excessive, and it is an advantage to made a duplicate enlarged negative. Any necessary retouching is also easier to carry out on this duplicate. See also page 472.

Duplicate negative making can be simplified in two ways:

(1) By printing the negative on a transparency material and processing the latter by reversal (see page 442). This is equally suitable for materials in groups (a), (b) and (c) on page 79. The manufacturers frequently issue instructions and formulae specially suited for reversal processing with their material.

(2) By using a direct duplicating film. This has a pre-fogged emulsion (see also page 499) which on exposure from a negative develops direct to another negative and so dispenses with the necessity of making an intermediate positive transparency. The exposure usually has to take place through a yellow filter. The sensitivity of this material is very low, and is comparable with that of a chloride contact printing paper. Enlarged duplicates can only be made with a very powerful light source.

Both the slow negative materials and positive films used on the one hand for duplicate negatives and the direct duplicating film on the other should be developed in a universal formula such as No. 12, 13 or 14 on page 334.

PAPER NEGATIVES

The paper negative is a useful intermediate stage of duplication, not because of its lesser cost compared with film, but because it makes local treatment or modification either by mechanical or chemical methods easy. Against this the main drawback of paper negatives is the fact that the paper support or base has a more or less pronounced texture which

detracts from the definition of the image when the paper negative is printed by projection in a normal enlarger.

This drawback is most marked when it is necessary to reproduce the finest detail of the picture. On the other hand it can be used to advantage in achieving artistic effects.

One way of reducing the texture effect of the paper is to make the enlarged paper negative through the back of its support instead of, as usual, through the emulsion or image side. The image obtained in this way looks irregular and shows the texture when viewed normally by reflected light. When however the picture is examined by transmitted light, the irregularities are reduced because the structure of the silver image itself compensates for the texture of the paper – though at the cost of image sharpness. On the other hand the paper texture with certain very thin based materials (generally document paper emulsions) is frequently negligible.

The paper negative process provides possibilities for a whole range of variations in graininess and sharpness, and hence of pictorial quality.

(1) To reduce the appearance of paper grain in the finished picture, an intermediate positive is made on a suitable film as described on page 420, with full exposure and full development. It is best to do this by projection printing in the enlarger. The paper negative is then made on a smooth and thin based negative paper, exposing through the paper base. The negative paper is laid, emulsion side down, on a sheet of black paper on the enlarger base board. The final positive can be made from the paper negative by contact, keeping the emulsion side of the positive paper in contact with the emulsion side of the paper negative.

(2) To preserve a certain paper texture in the finished picture the intermediate positive is made on paper, not on film. The paper is exposed through the base in the same way as described above. The effect depends on the character and properties of the paper used; a single-weight bromide or fast chlorobromide paper are most suitable. A paper with a thin and reasonably transparent base may be chosen for minimum grain. The correct exposure must be found by trial and error; on the average it will be some five times as long as required for an enlargement made normally with the paper emulsion side facing the light. The negative must also be inserted in the enlarger reversed, with the emulsion side to-

wards the lamp house, otherwise the final picture will be reversed left to right. Finally, it is wise to place a sheet of black paper under the paper being exposed on the enlarger base board, to reduce the risk of unwanted reflection.

From the paper positive the paper negative is prepared by contact copying, with the emulsion sides in contact. The final negative is made on a smooth negative paper which has a minimal effect on the grain in the final picture. The latter is then made by contact printing from the paper negative, with the emulsion sides in contact.

For greater graininess in the final print the intermediate positive may be made by projecting the original negative image on to the emulsion side of the paper and not through the base.

These methods by no means exhaust the possibilities of a paper negative. Additional scope is provided by the choice of material for the intermediate positive as well as the negative, to say nothing of the possibilities offered by retouching or other after treatment which can produce many further variations in the character of the final picture.

PAPER NEGATIVES FROM COLOUR TRANSPARENCIES

Paper negatives also provide a quick and simple way of making enlarged prints from colour transparencies (see also page 466), since the paper is much easier to handle in processing than a film.

For this the colour transparency is projected to the required size on a medium grade bromide paper. This should preferably be coated on a thin base of as uniform a texture as possible. Some makes of paper are more suitable for this purpose than others.

The resulting paper negative can then be printed by contact on a similar sheet of paper. For this purpose the paper for the positive is placed emulsion side up on the enlarger baseboard, covered by the paper negative (emulsion side down) and by a sheet of clean plate glass. The exposure then takes place by the light being projected through the enlarger lens, with no negative in the enlarger carrier.

According to the paper used, some paper grain generally remains visible in the positive print. This is no great disadvantage if a rough print only is wanted; otherwise the paper grain can be eliminated by any of the procedures

described on page 475 – though at the expense of some image sharpness.

A panchromatic paper used for the intermediate negative ensures better tone reproduction in the print.

If rapid processing papers suitable for roller processors are used, the production of the enlarged print is particularly quick. The paper negative can then be printed while still in a damp condition – which also tends to reduce the effect of the grain of the paper base. Glossy surface papers are less suitable for this technique, because the glossy surfaces tend to stick together more if the negative is not completely dry at the time of printing.

CONTACT PRINTING

This is used at certain stages of making intermediate negatives or positives (page 419) as well as for reference prints for filing, and for producing transparencies for projection from miniature and small-size roll film negatives.

The classical way of making contact prints is with a printing frame, and this is often the most convenient method where only occasional contact copies are required. As its name implies, the printing frame consists of a wooden or plastic frame containing a glass plate and a pressure plate held in place by a pair of flat springs.

The printing frame is loaded by placing it, glass down, on the table, opening the back, and inserting – in this order – the negative (emulsion side up), the paper (emulsion side down), and replacing the back and closing the springs. These press the paper into intimate contact against the negative and the front glass. (If glass negatives are used, the front glass plate is not needed.) The frame is then placed underneath a suitable light source, for instance a 60 watt light bulb about a couple of feet above the frame, and the lamp switched on for the required exposure time. With chloride contact papers this exposure is generally of the order of 5 to 10 seconds.

Printing frames are available in various sizes from 6×6 cm upwards. The enlarger itself – again where contact printing is used only for auxiliary special operations – can also be the light source, in which case the frame is placed on the enlarger base board and the enlarger lamp switched on without a negative in the carrier. The light beam projected

by the lens then exposes the print. Exposure times can be found by test strips or by placing a step wedge negative between the negative and the glass plate of the frame.

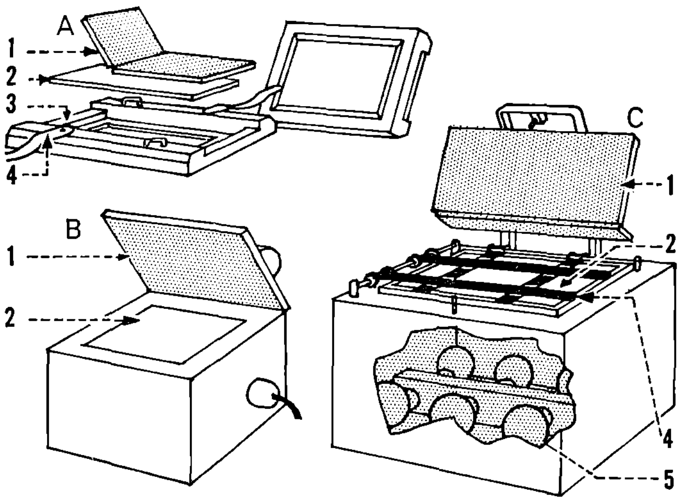
Some printing frames are fitted with register pins to permit accurate registration of punched negatives and positive films (page 192).

Where contact printing is done on a larger scale, a printing box is usually more convenient. In its simplest form this consists of a box containing one or more lamps for even illumination of a sheet of opal glass which forms the top of the box. The negative is placed on this glass, emulsion up, covered by the paper with emulsion side down, and pressed down into intimate contact by a hinged platen. The latter is usually lined with felt, foam rubber or a similar substance to ensure uniform pressure over the whole negative area. Such printing boxes may have printing apertures from 6 $\times$ 9 cm or $2\frac{1}{2} \times 3\frac{1}{2}$ inches up to 30 $\times$ 40 cm or 12 $\times$ 15 inches, or even larger for document copying (page 497).

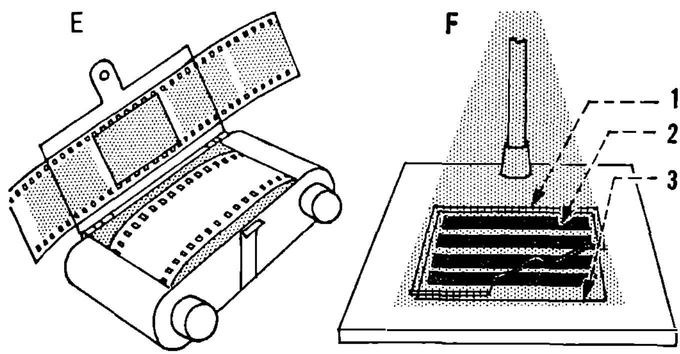
Refinements of more advanced printing boxes include an internal orange or red lamp to facilitate positioning of a negative, automatic platen operation by a foot pedal, automatic masking strips for white borders, and in some cases roll paper feed as well. Contact printers used in photo finishing establishments may incorporate automatic exposure measurement and timing, arrangements for stamping the back of the print etc.

Larger printing boxes have a number of separate lamps installed below the printing area for even illumination. Sometimes these lamps can be switched individually for a certain amount of local exposure control analogous to shading in enlarging (page 412); no very exact local control is however possible.

Special contact printers for 35 mm film strips consist essentially of a magazine holding 35 mm positive film and threading it from a feed spool to a take-up spool past a printing window. The negative strip can be run through this window in contact with the positive film. The exposure may be made underneath an enlarger. After every exposure the film is advanced in the magazine and the next negative brought into position. After processing the positive film this yields a film strip – for projection or for cutting apart and



The printing frame A consists of a frame 3, a glass plate 2 and a pressure plate 1 held in place by springs 4. A printing box B incorporates its own light source at a standard distance from the glass plate 2. The platen 1 presses the negative and paper together. A professional printing box C may incorporate masking strips 4 for different formats and a number of lamps 5 to cover a large area evenly.



Contact prints of 35 mm. films can be made in a strip printer E, a magazine holding a continuous roll of 35 mm. perforated paper. The negative strip is pressed into contact by a transparent pressure plate. A simpler way (F) is to place strips (2) of 4 or 6 negatives on a sheet of bromide paper 3, cover with a glass plate 1 and expose by the light beam from the enlarger.

mounting as separate miniature transparencies. The strip printer can also be loaded with perforated positive paper for making contact strip prints.

CONTACT REFERENCE SHEETS

Where contact prints of a full length of 35 mm or roll film negatives are required, individual printing wastes a lot of time. If the negatives are reasonably uniform in density and contrast they can be printed together. For this a 20 × 25 cm or 8 × 10 inch sheet of enlarging paper is placed on the enlarger base board, the negatives laid out in strips with their emulsion side down, and covered with a sheet of clean plate glass to hold them flat. An 8 × 10 inch sheet of paper can accommodate a dozen $2\frac{1}{4} \times 2\frac{1}{4}$ inch negatives in three strips of four, or 36 negatives 24 × 36 mm in six strips of 6. (The outermost perforated edges of the outer strips will not be on the paper any more, but this rarely matters.)

The whole film is then exposed together by switching the enlarger on and off for the required time. The correct time can be found beforehand by a few tests; if the negatives are uniform in density from film to film (which they usually are in professional practice where camera exposures are fairly precisely measured by meter) the same enlarger setting and exposure time will serve for all occasions.

Odd negatives which have printed too light or too dark can always be reprinted separately, but as long as the image is reasonably recognisable, the reference print serves its purpose.

Such reference sheets are useful also in showing the negative numbers on the edges of the film and so help in quick identification of pictures which are selected for subsequent enlarging.

Special printing frames exist which take strips of film in this way for simultaneous printing; here the frame is simply placed on the enlarger baseboard after loading. Alternatively the multiple print can be made on a large size printing box (for example as used for document copying) on a suitable contact paper.

COMBINATION PRINTING

Occasions arise both in pictorial work and for special effects in commercial and advertising photography, where the final

print is made up of elements from more than one negative.

An obvious way of doing this is by taking two or more prints, cutting out the required picture elements and mounting them together on one print – so-called cut-and-paste montage. This composite print is then rephotographed, and final prints made by enlarging the combination negative. Cut-and-paste montage requires careful working, especially to hide the pasted-up joins (generally achieved by thinning the edges of pasted-on picture elements) and care in re-copying. The final print usually loses some tone gradation and tone detail in the process.

A more elegant way is to expose several negatives or parts thereof on the same sheet of paper. There are three basic techniques:

(a) We can combine a pair of negatives in the negative carrier and enlarge them together.
(b) We can print different negatives in succession on top of each other on the same sheet of paper.
(c) We can print different negatives or parts therefrom into different areas of the print. This usually requires shading of part of the image area during each exposure.

Combination in the Negative Carrier. This is similar in principle to the combination of a negative and a texture screen in a negative carrier (page 436). Where two separate negatives are used, their images overlap and their densities are additive. In other words, the darkest print tones are determined by the areas in the sandwich where both negatives are clear, and the lightest print tones where both negatives are dense. This tends to increase the density range of the combination, so that the component negatives should not be too contrasty themselves.

This type of montage is best suited to combinations where highlight details of one negative can be located in shadow areas (preferably clear film portions) of the other and vice versa. It may be necessary to make an enlarged duplicate of one of the negatives to bring the image portions to be combined to the required relative scale.

This method can also be used to simulate the effect of falling snow or rain. For this purpose an unexposed plate or film is fixed out without development, and after washing

and drying sprayed over with a concentrated solution of red dye. The drops adhere to the gelatine emulsion and after drying form the "snow negative" which is sandwiched with the picture negative in the carrier of the enlarger. To make the "flakes" sufficiently out of focus, it may be necessary to use one or two clear glass sheets between the negative and the "snow image". It is also necessary to adjust the size of the dye droplets so that they appear on a suitable scale in the enlargement.

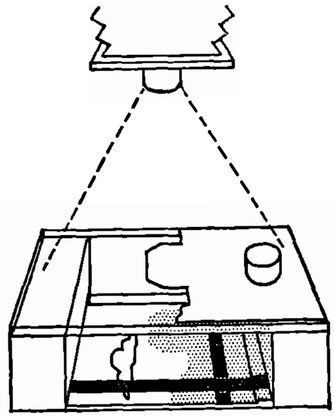
Combination by Successive Exposures. This is similar in principle to the type of combination printing employed in tone separation (page 418). The darkest tones on the print are here determined by the shadows of either of the negatives, and the lightest portions by the areas where both negatives are dense. Combination of this kind does not require specially soft negatives; but each component image should be as dense as possible in the areas where detail is to print from the other negative. The two images should be similar in contrast, but the negatives may be of different size since the degree of enlargement can be changed between the exposures. The exposure time has to be found by trial and error.

In contrast to the first method, overlapping image details add in density on the print and not in the negative.

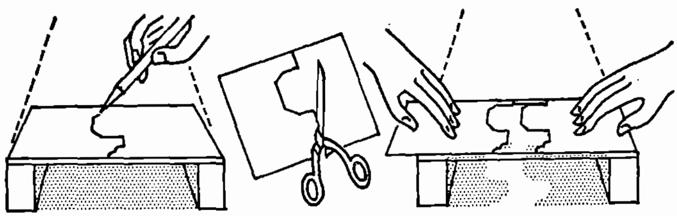
Combination with Masking. This is the most flexible method as far as the choice of component images is concerned, since each is printed separately in its own area on the final print.

The simplest application of this method is printing in clouds into a landscape negative with a bare sky. For this purpose the landscape negative is first printed on the paper, while the sky area is shaded during this exposure. The enlarging paper is then removed (but without shifting the position of the paper holder) and a suitable cloud negative projected on the baseboard. The cloud should of course match the landscape picture in illumination, scale and contrast. The enlarging paper is then replaced on the baseboard, and the cloud printed on it while the foreground area is shaded.

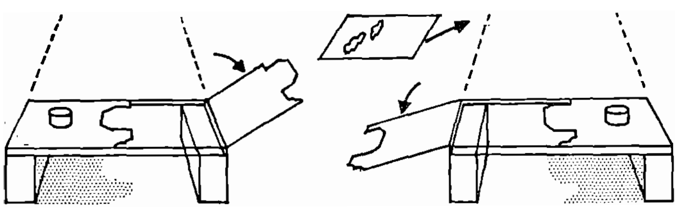
To facilitate accurate shading during the two-part exposure a masking stage is useful. In its simplest form this may consist of two boxes or blocks of wood of identical height placed to the left and right of the enlarger baseboard. On top of the boxes is placed a sheet of clean plate glass.



To combine elements from different negatives on the same print, masks can be placed on a glass plate supported above the printing paper. The mask holds back the area printed from the first negative while the second negative is being exposed.



The first step is to focus the first negative on the baseboard, then place a piece of opaque paper on the glass plate and trace the image outline to be printed on it (*left*). The paper is then cut in two along this outline (*centre*) and the two halves fitted together in register with the image as mask and countermask (*right*).



To print for instance clouds into a cloudless picture the mask of the foreground is removed (the sky countermask being held in place) while the foreground negative is printed (*left*). This is then replaced by the cloud negative, the latter appropriately located, and the foreground mask placed in the previously determined position while the sky mask is removed to print the clouds (*right*).

This glass will then lie between the projection lens and the paper on the baseboard. The landscape negative is placed in the negative carrier, and focused in the ordinary way on a piece of plain paper on the baseboard. A second piece of plain (but preferably opaque) paper is then laid on the glass sheet. The image of the negative on it will still be sufficiently sharply defined to permit sketching in of the horizon line with a pencil. If image details project into the sky area from the horizon, they may either be drawn in on the paper or else painted on the glass itself with a brush.

The paper is now cut along the horizon line to form two masks. The mask covering the sky is first placed in position, and the landscape negative is printed on the paper below. After that the foreground mask is placed in position so that it exactly meets the sky mask, the latter removed and the landscape negative replaced by suitable cloud negative. A second exposure is then given and the composite print developed. The two masks are best held in position during the respective exposures by small weights or appropriate clips.

If an outline mask of this kind is made at a certain magnification, the two complementary parts of the mask can only be used to screen the unwanted parts of the image on bromide paper when the two negatives are used at the same magnification. If the scales of the two negatives are different and the enlarger has to be refocused with the second negative in position, the light rays from the enlarger lens will pass through the mask at a different angle, so that the area shaded by the mask on the easel will be different. Hence when two negatives are used at different magnifications, a new mask of the same general shape but of different dimensions will have to be cut. The lower the glass stage is above the printing paper, the less will be the difference between the two masks. Also the shadow of the mask will be sharper, but it must be cut more precisely.

This process is not merely useful for showing clouds in an otherwise empty sky, but is one of the most flexible techniques known to enlarging. For instance we can transfer a portrait taken out of doors into a background of a room, place an interior portrait against an outdoor background, have the same person appear several times in the same picture, place a model ship on genuine sea waves, and so on.

TONE ABSTRACTION

A variety of photographic design effects depends on converting the continuous-tone image of a normal photograph into shapes of just black and white. This may be done by successive recopying of a negative on high-contrast film. When the negative is first contact printed or enlarged on a contrasty positive film, some of the intermediate tones disappear. By reprinting this transparency on another high contrast film a far more contrasty duplicate negative is obtained. Repeating this procedure leads to a negative – or positive – consisting only of black and white with no intermediates.

Extreme contrast materials used in the graphic arts field, so called lith emulsions, are most suitable for this purpose for they reduce the number of intermediate negative and positive stages to a minimum.

Negatives with comparatively fine detail rather than very broad areas are most suitable for this technique; so are detailed semi-silhouettes.

The last high contrast negative without intermediate tones can be printed with an exposure to produce a black image in the positive or only a grey one of any desired depth. To create an image with a range of tones different negatives can be combined in succession, printed to give overlapping black, medium grey, light grey etc. positive images.

POSTERIZATION

This is an application of the multi-tone technique just described to the tone separation process discussed on page 408. It produces a picture in which all the elements are built up of one or other of three or four tones only. The result has something of the quality of a high-grade poster, while the increased tonal range seems to give it a degree of extra modelling. When viewed at a proper distance, the effect is free from the appearance of any mechanical treatment, yet retains the exact physical accuracy of the original.

Though the range of subjects suitable for posterizing is practically unlimited, for a first trial a subject of good contrast, with many lines and much confusing detail is recommended.

In its simplest form this involves making two negatives

which, as in the tone separation process, record only the highlights and shadows respectively. In this case however both highlights and shadows in their respective negatives are reduced to one tone only by high-contrast reprinting. The material used for intermediate positives and negatives should be a high contrast process film developed in a contrasty developer; a lith film (and the developer recommended by the manufacturer) is ideal. These films are usually coated on a polyester base of particularly high dimensional stability which helps to keep all images in accurate register. If the original negative is not too small, the intermediate positives and separation negatives can be made by contact printing. Otherwise the intermediate transparencies are best made by enlargement, taking special care that the magnification is absolutely identical for both transparencies. The final negatives are then best contact printed from the transparencies.

This is the procedure:

1. From the original negative make a contrasty positive transparency with a short exposure to record only the shadows. These should be as black as possible, with medium tones and highlights virtually transparent.

2. From the same negative print a second transparency giving considerably more exposure so that the extreme highlights are clear, but middle tones and shadows go completely black. The exposures for transparencies No. 1 and 2 will have to be found by separate tests; they are likely to be in the ratio of about 1:5.

3. From the shadow transparency No. 1 make a shadow negative. This should receive sufficient exposure to print the medium tones and highlights fully black, with only the shadows as clear film.

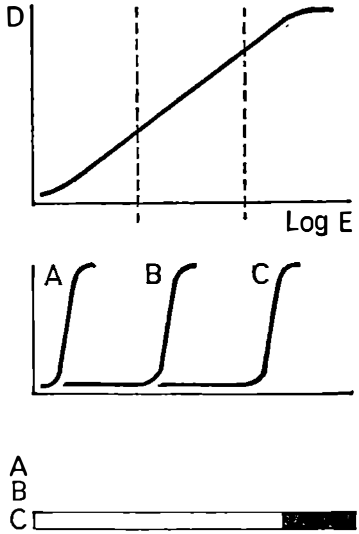
4. From the highlight transparency No. 2 print a highlight negative in which the highlights only are full black and the medium tones and shadows clear film.

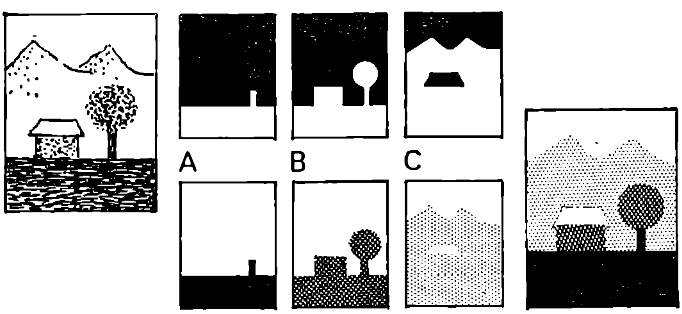
5. Print the shadow negative No. 3 on to a contrasty paper, giving sufficient exposure (determined by separate test) to record the shadow tones (the transparent areas of the shadow negative) as full black.

6. Print the highlight negative in register on the same sheet of paper, but giving only enough exposure for the medium tones and shadows (the clear areas on this negative) to record as light to medium grey.

POSTERIZATION

The aim of this process is to split up the tone range of a normal negative into three (or more) negatives of very high contrast, switching over from white to black at different points of the original negative curve. Here the shadow negative A records the deepest shadows as transparent film, and everything else as black. The medium tone negative B splits in the middle of the range: shadows and lighter medium tones are transparent, darker medium tones and highlights full black. The highlight negative C records only the extreme highlights as black and everything else transparent.





To combine these images, the shadow negative is printed with a long exposure to give full blacks on the print, the medium tone negative with a shorter exposure to render its areas dark grey, and the highlight negative with a still shorter exposure to add the light grey tones to the same print. The result (*right*) then shows only the three basic tones (plus white) but no tone gradation.

The resulting print now shows three tones only: white in the extreme highlights, black in the full shadows and grey everywhere else.

When printing together, the image of the highlight and shadow negatives must of course be in accurate register. To ensure this the same methods can be used as described for tone separation (page 418). To minimise any dimensional changes between the images (negligible in any case if films on polyester base are used) the highlight and shadow transparencies on one hand and the highlight and shadow negatives on the other should be fixed and washed for as nearly as possible the same length of time, and hung up to dry from the same relative corner.

For a posterization with four tones (white, light grey, dark grey and black) three separative positives and negatives are required. The highlight and shadow positives and the negatives are the same as before; a medium tone positive should record the shadows and darker mid-tones of the original as full black, and the highlights and lighter medium tones as transparent film. The corresponding mid-tone negative will then be completely clear in the areas corresponding to the original shadows and darker tones, and fully black in areas representing highlights and lighter medium tones. The exposure for the mid-tone positive will accordingly be somewhere between the exposures for the highlight and shadow positives.

When the three negatives are printed in succession on the same paper, the highlight negative is printed just long enough to record a light grey tone over the whole print except the extreme highlights. The medium tone negative is printed for a longer time to yield a medium to dark grey tone, and the shadow negative longer still to record the shadows full black.

The three printing exposures again have to be found by separate tests. The correct exposure when printing the mid-tone negative should give a lighter grey than is wanted on the final print, since the mid-tone on the latter is produced by the additive exposures through the highlight and the mid-tone negatives.

As explained above, each separate negative for a posterized print should consist only of black image area and transparent film. If a negative still retains some gradation be-

tween the two, this can be eliminated either by quick treatment in Farmer's reducer (Formula No. 48 on page 446) or by making a further high-contrast transparency and negative.

The posterization effect can be adjusted within wide limits by selecting the point at which the tones split in each negative. This is controlled by the exposure time in printing the first stage separation transparency. If desired, posterization is also possible with four negatives to produce five tones: white, light grey, medium grey, dark grey and black.

LINE IMAGES FROM CONTINUOUS-TONE PICTURES

Another approach to tone manipulation is the elimination of tones altogether – turning a continuous-tone photograph into a pure outline one. Three main methods available for this are:

(a) Combination of negative and positive images;
(b) Pseudo-solarisation techniques;
(c) The use of equidensity materials.

A negative and a positive from it, of equal contrast and combined in complete register, should of course cancel out. If the two are separated by a thin glass plate and contact printed in a printing frame underneath a large diffused light source, some light seeps through the outlines of the image. This produces a toneless but detailed line image. This image is a positive (black lines on a white background). It can also be made on a film and the latter printed or enlarged to produce a negative outline image. Alternatively, a negative made from the intermediate outline positive can then yield further outline positives in a single and simple printing operation.

If no suitable large diffused light source is available for the above procedure, the negative/positive/glass plate/film sandwich can be mounted on a gramophone turntable and set spinning while a single lamp shines down at an angle (page 491). This way the light creeps round the outline from all directions. The thicker the glass plate, the thicker the outline. A very fine outline is obtained by using an extremely thin plate or even a piece of transparent film.

With the same arrangement but the printing frame stationary and a single light source shining from one side, the outlines are shadowed.

If a pseudo-solarised image is recopied on a high-contrast material, the tone differences can be made to disappear – especially with multiple recopying. The result is again an outline of the picture, though this is different in character to that obtained by a negative-positive combination. If during recopying the pseudo-solarised image is again solarised, each outline is split up into further outlines resulting in second-order solarisations.

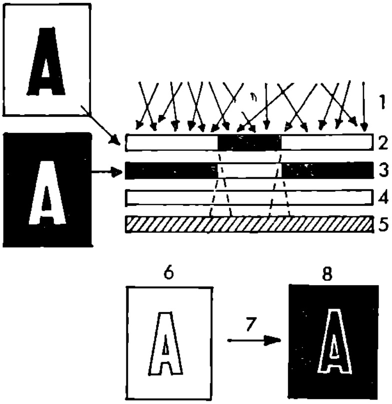
While the above procedures are comparatively laborious, a special equidensity film such as Agfacontour provides pseudo-solarised outline images in a single working stage. The equidensity film consists of a combined silver chloride and silver bromide emulsion which is positive working at one exposure level and negative working at another. This is achieved by combining a physical development process (similar to direct-positive paper emulsions) and normal chemical development. The resulting curve is thus completely unlike a usual characteristic curve – it is straight and horizontal with a sharp dip and rise again in the middle (page 491).

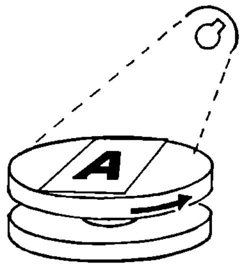
At the exposure levels corresponding to the horizontal portions – before and after the dip – the film is fully blackened on development. In other words, no exposure and a high exposure both yield black film, though by different processes in the development chemistry. Between these two levels, at a point corresponding to the dip in the curve, the emulsion yields no image, i.e. transparent film. The no-image range may cover a log exposure range of as little as 0.1. It is thus a specific density level in the original image (the negative – or a positive transparency – being printed on Agfacontour film) which registers as an outline image.

The greater a density gradient in a photograph, the sharper and better defined the outline becomes. But by suitable choice of the printing exposure, different density levels of the original image can be converted to outlines. (This was in fact the original purpose of the film – to record equidensities or lines joining image portions of equal density.)

The image produced on the Agfacontour film is always a white (thin) outline against a black background. If a first-order image (i.e. one produced by direct printing from a continuous-tone negative or positive) is reprinted on another Agfacontour film, each line is resolved into two finer lines representing a specific density level to each side of the first-

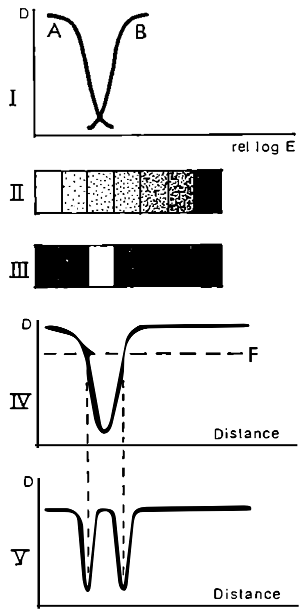
LINE CONVERSION





A straightforward tone-line conversion involves sandwiching a positive (2) with a negative of equal contrast (3) in accurate register and exposing this plus a spacer (4) and a sensitised film (5) below a diffused light source (1). As light creeps round the outlines of the negative and positive images, a negative line image (6) is formed. Printing this on bromide paper yields a positive outline image (8).

Instead of a diffused light source, the sandwich can be placed on a gramophone turntable and illuminated from one side by a single lamp (*right*).



I. An equidensity film like Agfa-contour has two sensitometric curves of positive (A) and negative (B) working characteristics. On printing a continuous-tone negative (symbolised here by the grey scale II) on the equidensity film, all tones except those corresponding to the dip in the combined curves register black (III), so forming the outline at a particular exposure level.

IV. The outlines formed in the first place is not always very thin and may not be quite sharp; the plot here shows the change of density across the line. If this is printed on a further equidensity film, the latter records only two specific density levels F on each side of the line; as a result the line is split up into two very fine and sharp outlines (V).

order outline. The result is a second-order equidensity and is usually completely free from tone areas. The double outline is often more attractive pictorially, too. To obtain a positive outline image (black lines on white) the Agfacontour image (whether first-order or second-order) is printed on a normal bromide paper.

Using such an equidensity film is as straightforward as using a negative-positive material. The film is however orthochromatic in sensitivity and therefore needs handling by an appropriate red darkroom safelight. For optimum sharpness of the outlines the material should be exposed by yellow light (a yellow filter in front of the enlarger lens). Exposures are ascertained by trial and error and the film is developed in a special developer supplied by the manufacturer. The processing steps consists of 2-3 minutes of development, a stop bath for 30 seconds, 5 minutes for fixing and a final wash.

LETTERING

Lettering is often required in photographs used for advertising layouts, book jackets and similar purposes. In many cases this is produced by hand work on the final print – e.g. by air brushing or painting on a transparent plastic overlay combined with the print before it is recopied for photomechanical reproduction. Lettering can however also be printed in photographically and the methods depend on the type of lettering required. This may be:

(a) Fully black letters on the print. They are best placed in areas of lighter tone.
(b) Completely white letters on the print, best placed in areas of medium to dark tone.
(c) Medium tone lettering through which the image of the picture shows up darker.
(d) Medium tone lettering through which the image shows up lighter.

Black Lettering. The straightforward way of printing in black lettering is to prepare a separate lettering negative, of the same size as the picture negative, in which the letters are arranged in the required position for layout and show up transparent against a dense black blackground. The easy

way of doing this is to draw or paint the letters in indian ink on a large sheet of white paper, and copy them at the required scale with a camera. The picture negative and lettering negative are then printed in succession on the same sheet of paper, exposing sufficiently long through the lettering negative to record the letters fully black on development.

An alternative way is to draw the letters in black in the correct layout on a sheet of paper or clear plastic of the same size of the final print required. This lettering original is then contact printed on a high contrast transparency film which on development should be completely opaque with transparent letters. After the main exposure of the print to the picture negative, this lettering film is laid over the paper and held down with a sheet of plate glass while a further exposure (without a negative in the enlarger) prints in the lettering.

White Letters. This requires a lettering negative similar to that used in the first method, but here we make a contact positive from the negative, showing again black letters against clear film. This lettering transparency is superimposed on the picture negative in the carrier of the enlarger, and the two simply printed together.

Alternatively, the lettering may be drawn on a sheet of clear plastic of the same size as the final print, and in the required layout. This sheet is placed over the enlarging paper during the normal printing exposure (again held down in close contact with a sheet of clean plate glass).

Ghosted Letters. Either of the above methods can be adapted to produce lettering with parts of the image showing through it. If the lettering negative (transparent letters on black background) is printed by a separate short exposure, the image on the print will show through darker on medium grey letters. If the lettering positive (dark letters on transparent film) is given a short exposure and soft development to make the letters no more than light to medium dense, this negative combined with the picture negative in the carrier of the enlarger will print the letters lighter against the image, with the latter still showing through.

GRAPHIC DESIGN EFFECTS

Commercial photography, especially in advertising, frequently calls for more or less abstract designs and patterns

based on photographic images. These can be produced by various combinations of some of the special printing effects described so far, such as tone abstraction (page 485), posterization (page 485), combination printing (page 481), masking (page 424), the use of screens (page 435), and so on. More than any other region of photography this is a field of experimentation with immense scope for imagination. As with all work off the beaten track, successful results depend on visualizing the effect desired and then selecting the most appropriate methods to achieve it. Trying out various procedures to see what comes of them is valuable to acquaint the operator with the processes possible and the best way of applying them. But the final effect should be a deliberate one. The odds against successful results from unplanned trying of different processes are considerable.

It goes without saying that the subject itself of the picture greatly determines the choice of the technique employed for modifying it. The aim should be to accentuate an inherent visual characteristic of the subject – in terms of tone, pattern or outline – or to suggest aspects which are not visible at first sight.

The effect may be realistic, imaginative or bizarre. As in all visual art, the success of a presentation depends on the response it evokes in the beholder.

The list below suggests just a few of the immense possibilities.

(1) The combination of a negative and a same-size positive made from it can be enlarged slightly out of register. This yields so called bas-relief pictures, simulating relief effects which extend even to strictly two-dimensional items such as cast shadows. (In complete register, such combinations can yield outline images – see page 489.)

(2) Combination of a negative and a transparency derived from it but reversed left to right is only one of many possibilities of negative-positive duplication.

(3) Deliberate unsharpness can produce its own effects. Movement can be simulated by displacing the paper slowly in one direction during the enlarging exposure.

(4) This movement need not be continuous, it can proceed in stages, yielding multiple displaced images. Similar multiple images are possible by successive exposures of the same negative at slightly different magnifications.

(5) In negative-positive combinations (and indeed in all multiple printing processes) one of the images can be blurred (for instance by defocusing) and the other or others sharp.

(6) Pseudo-solarization can be applied in a number of ways, for instance combined with high-contrast abstraction, (page 439). Either the intermediate positive or the final negative – or both – may be solarized in this way.

(7) Pseudo-solarization can equally be combined with bas-relief or other negative-positive combinations.

(8) High-contrast abstractions (page 485) can be combined with texture screens. If the negative is sandwiched with a screen in the carrier of the enlarger, the shadows take on the screen pattern. If the screen is used during an intermediate positive stage, the highlights are screened.

(9) In negative-positive combinations or in posterised pictures (page 485) one or more of the component images can be screened. The different separation positives or negatives (or both) can even be printed through different screens for combination effects.

(10) A paper negative (page 413) can be used at one or more stages of posterisation procedures. In this case the paper grain will show through the appropriate image tone.

(11) The screening and solarization techniques described above can equally be applied to lettering included in a picture.

Pseudo-solarization can give letters a white or dark outline, according to the stage where it is applied. The use of screens when preparing lettering negatives or positives breaks up the letters themselves by the corresponding screen pattern.

(12) A wide field is opened by photograms which are enlargements without a negative. In its simplest form a photogram is a shadow picture of various objects (paper clips, granulated materials like rice, cut-out shapes in tissue paper etc.) placed on the enlarging paper while the latter is exposed by a uniform light beam from the enlarger lens. The objects can also be solid ones, and items such as glass or plastic dishes yield various patterns composed of sharp and unsharp shadows.

(13) Photograms can in turn be combined in various ways either by multiple exposures of different lengths or by recopying the photogram and combining it with texture

screens, solarization techniques, multiple printing methods etc.

(14) All the above procedures are equally applicable to colour. Colour printing can be used in the final stages or for intermediate as well as final images. Thus it is possible to combine colour negatives and positives, print tone separation or posterisation images in register on colour paper, using differently coloured light for each of the exposures, and so on. The same applies to high-contrast abstractions, texture screens and all combination printing procedures. In every case the different part exposures can be made through different filters, with different exposure times etc.

When colour is brought into special graphic effects, the scope extends into an additional dimension. The results however become rather unpredictable, and a great deal of trial and error experimenting may be needed – with different exposure times, colour filters and combinations – to achieve exactly the desired effect. On the other hand, a given set of intermediates – for instance tone separation negatives – can yield any number of alternative colour combinations by simply changing the filtrations, light colours and other factors involved at each intermediate stage. The possibilities here are truly endless.

Document Copying

The reproduction of documents, articles and illustrations from periodicals and similar material is fairly closely linked with positive printing technique, partly through the use of enlarger equipment and partly by the sensitive papers and processing systems employed. There are three main types of work to be considered:

(a) Copying documents with an enlarger;
(b) Contact copying with a printing box;
(c) Re-enlargement of microfilm negatives.

Of these, document copying processes belonging to group (b) above have expanded particularly in recent years and are employed in many office copying systems.

Documents can also be copied on high-contrast document papers by exposure in cameras specially designed for the purpose. These may incorporate provision for immediate processing, after which the negative is either used as it stands or rephotographed to get a positive. Where negatives are to be used directly, the camera photographs the original via a mirror or prism to get a right-reading copy instead of a laterally reversed one. The use of copying cameras of this type has however largely declined with the increasing popularity of office copying machines of the type described below.

Copyright legislation restricts the use which can be made of such copies from published articles, photographs etc. Generally they can however be utilized for purely private purposes (but not for general distribution).

COPYING WITH THE ENLARGER

This is the method employed when originals are to be copied on a reduced scale. In the optical sense of the term (as distinct from chemical reduction – see page 430) reduction is the opposite of enlargement: the object of the system is used to produce a copy in a smaller size than the original. In commercial practice this is often done with a copying camera,

but more advanced enlargers have both the facilities (see page 196 and 197) and the necessary optical precision to do the job equally well.

For copying the original is placed on the baseboard or easel and illuminated there, and the sensitive material located in the negative carrier. The enlarger modifications required for the purpose are the lighting equipment to attach to the baseboard and a dark slide and possibly special focusing aids for the film in the carrier.

As in every kind of copying, the original must be evenly illuminated. To ensure this, powerful lamps like those used for photographic studio lighting are placed around the original. Since it is not usually possible to remove the enlarger lamp house for focusing, a test plate is placed in the negative carrier and the enlarging scale and focus altered until the image of the test plate is sharply projected on the original, and is of the same size as the latter.

The test plate is then replaced by the dark slide with the plate or film, and after switching off the enlarger lamp the exposure can be made by turning the lamps around the base board on and off for the required time.

The negative material should be chosen to suit the type of original. Drawings, documents and other line work is best copied on high-contrast process film or plates developed in a contrasty developer (for example No. 36 on page 443). Continuous tone originals should be exposed on a slow film or plate of medium contrast and developed in a universal developer like Nos. 12 to 14 on page 335, possibly used at a higher dilution.

CONTACT COPYING

This is carried out on contact printing boxes – scaled up versions of a contact printer as described on page 479, with an opal or ground glass sheet as the printing surface, mounted above a box containing anything from four to a dozen regularly spaced lamps for even illumination. Printing boxes of this type are produced for originals of maximum sizes from about 23 × 35 to 45 × 60 cm or 9 × 14 inches up to 18 × 24 inches, or even larger for engineering drawings. The most popular office copying size is about 35 × 45 cm or 14 × 18 inches which can handle the majority of documents met with in ordinary office practice.

Office copying systems at one time relied heavily on contact copying on photographic paper which was then processed by stabilisation or other methods to yield a nearly dry print. In view of the inconvenience of handling messy solutions in offices and other attendant drawbacks (risk of stain etc.) wet processing systems have virtually disappeared from the office copying scene in favour of all-dry methods such as electrophotography and heat copying (page 507–508). The following account of chemical and material systems is thus more of historical than of current interest but illustrates some of the permutations and combinations of light and chemical action involved. In terms of image quality and clarity these were often better than current electrophotographic and heat copying systems and are occasionally still in use where quality considerations are paramount at the expense of convenience and even permanence.

Main systems employed in this field have included:

(a) Ordinary document papers. These produce a negative image from the original (white lines or writing on black from black lines on white) and need reprinting to get a positive copy.

(b) Papers with incorporated developing agent (see also page 78) for rapid processing. The immense convenience of stabilization processing in office copying practice has largely ousted the more conventional document papers of group (a).

(c) Direct reversal papers. These have a pre-fogged emulsion which on further exposure to yellow light (with a yellow filter sheet on the glass plate of the copying box) yields a positive image from a positive original. This eliminates the negative stage of copying, but is useful only in exposure arrangements which yield the right-reading copy (see below). Direct reversal papers may be either designed for conventional developing or incorporate developer chemicals for stabilization processing in roller processers.

(d) Transfer-diffusion or diffusion-transfer papers produce a negative and a positive in a single processing stage, but on separate supports. The positive is produced on a non-light sensitive material by

chemical interaction with the negative, with which it is in contact during processing. In some versions of this process one negative can yield a number of positives (usually up to 6 or 8) by direct chemical interaction.

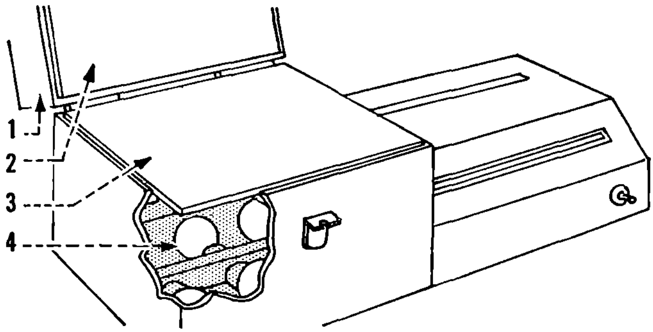
(e) Matrix papers, where again a negative is produced as in transfer-diffusion, and positives (up to about 8) derived by transferring dye from the negative matrix on to ordinary paper.

The negative paper for transfer-diffusion incorporates a developing agent, while the positive paper, which is not light sensitive, contains development nuclei. These render unexposed silver halide complexes developable. The positive paper may incorporate a silver halide solvent. After exposure the negative and positive papers are briefly soaked in an alkaline activator solution which may also contain a silver halide solvent, and then immediately squeegeed into contact, emulsion to emulsion. The negative image develops in the negative paper, while the unused silver halide diffuses into the positive layer where it is reduced on the spot to metallic silver, forming the positive image. Transfer-diffusion papers for multiple positives have a higher silver halide content, so that only part of the unexposed halide is used for the positive print. Further positives can be obtained by squeegeeing the activator-soaked negative and further sheets of positive paper into contact. After processing, which takes about one minute, the negative and positive are peeled apart.

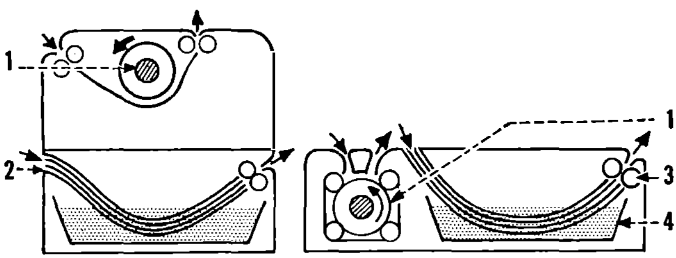
Transfer-diffusion papers are also processed in roller processers, but of somewhat different design. There is only one solution, and one set of rollers. The papers are passed into the machine together but through separate slots until they are seized by the rollers and squeegeed together as they emerge from the processer. This arrangement assures the brief pre-soaking necessary to take up activator before the two papers are pressed into contact. Transfer-diffusion positive papers also exist coated on both sides, and can be contacted with two negatives to give two-sided copies.

PRINTING ARRANGEMENTS

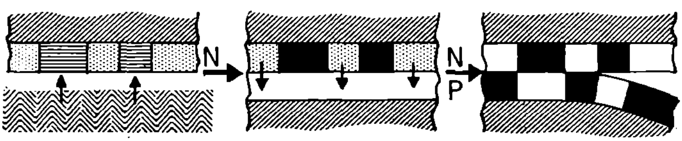
There are several ways of contact copying documents and other originals, depending both on the nature of the original



The typical document photo copying unit combines a printing box (in principle a large size contact printer) with a roller processing system similar to that shown on page 233. 1, lid; 2, pressure plate; 3, diffusing glass plate; 4, lamps.



Transfer diffusion copiers. Combined copiers and processors for flexible documents like letters may pass the original and copying paper round a transparent or translucent drum 1 with the light source inside. The exposed negative paper is then fed at 2 into the processing slots through the activator bath 4 to emerge squeegeed together by the rollers 3.



In the transfer-diffusion process the negative paper first develops a negative image as it goes into the activator solution (*left*). Squeegeed in contact with the positive paper, unexposed silver salts (shaded) migrate into the positive layer (*centre*) and are there converted into black silver (*right*). About ½ to 1 minute later the negative and positive can be stripped apart.

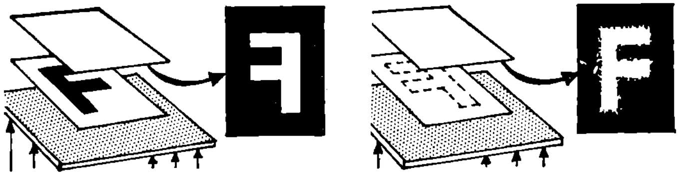
(whether it is single or double sided, on opaque or translucent base) and on the process employed.

(1) Single-sided originals on a thin and reasonably translucent base can be printed by transmitted light. The original goes face down on the exposing surface, and the document paper emulsion side down against the back of the document. This yields right-reading negative copies on papers of groups (a) and (b) above, and right reading positive copies on direct reversal papers of group (c).

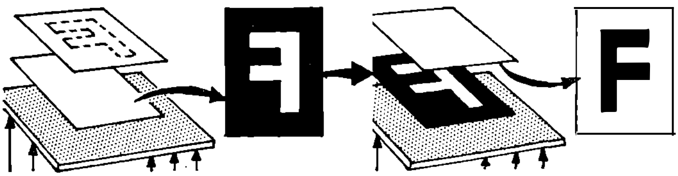
The image may be very slightly unsharp due to diffusion through the paper base of the document, but it is usually sufficiently readable.

(2) If a translucent one-sided document is placed face up on the exposing surface and the document paper emulsion side down in contact with it, the copy is reversed but fully sharp. This then needs recopying to produce a positive if papers of groups (a) and (b) were used, or simply to re-reverse the image with direct reversal paper of group (c). Transfer-diffusion (d) and matrix (e) papers yield the positive more or less directly from the laterally reversed negative – and can only work with such a reversed image.

(3) Opaque-based or double-sided originals are generally copied by reflex printing. Here the document paper goes on the exposing surface emulsion side up, and the document is placed in contact with the emulsion surface on top of the paper. The exposing light passes through the back and the emulsion of the document paper and is reflected back on to the latter by light areas of the original. Dark areas reflect back less light, and the contrast of the document paper must be high enough to record this difference in reflected light as a white image against a black background. The image is negative and laterally reversed, and used to produce a positive by printing through the negative in processes (a) and (b) above. This is also the method used for printing on modern dry copying materials as described on page 508. Transfer-diffusion (d) and matrix (e) papers again produce a positive by chemical or physical interaction between the negative and positive sheets in contact. The image produced in this way on the direct reversing paper-group (c) – is also laterally reversed, and must be recopied to get a right-reading print.

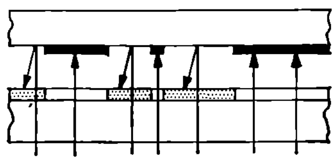


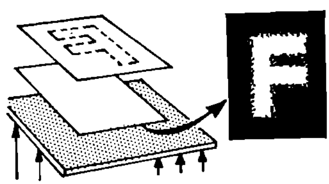
Left: Straight-through copying of a one-sided original, with the surface in contact with the document paper, yields a sharp and reversed negative. *Right:* For a right-reading negative the original goes face down on the illuminated printing surface. The result is slightly fuzzy.



For reflex printing the document paper goes face up on the copying surface, covered by the original arranged face down (*left*). The resulting sharp but reversed negative is then printed straight through (*right*) to yield a right-reading and sharp positive.

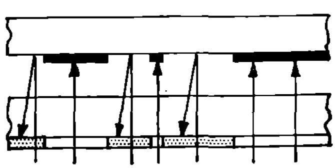
In reflex printing light passing through the base and emulsion of the document paper is reflected back by the light parts of the original to yield dark areas in the print.





Left: For bi-reflex printing a thin document paper goes face down on the printing surface, and the original face down on top of the paper. The resulting right-reading negative is somewhat blurred.

The image in bi-reflex printing is found in the same way as in reflex printing, only the positions of the document paper base and emulsion are inverted.



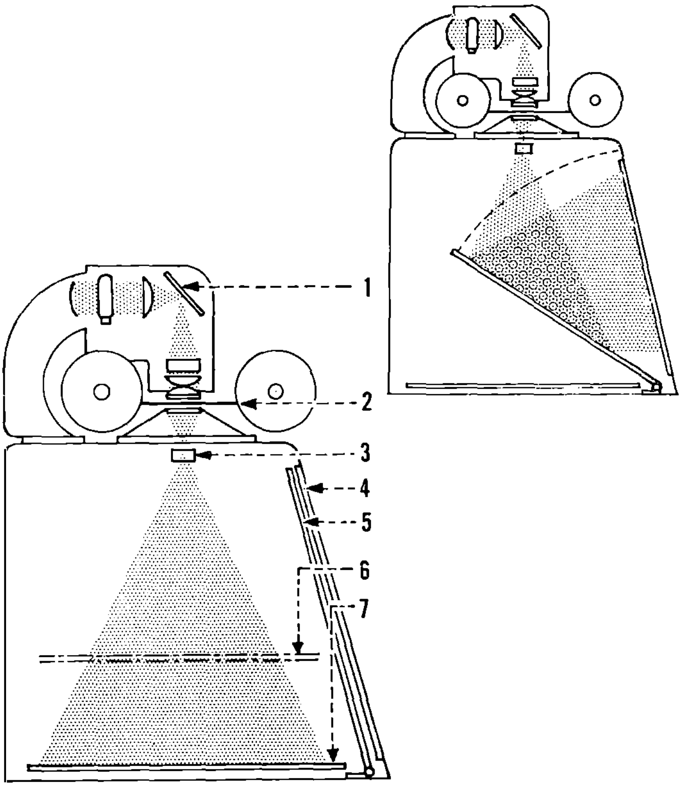
(4) Opaque or double-sided originals can also be printed by the bi-reflex method to yield a right reading copy – negative or positive according to the process used – in one step. Here the document paper is plaecd *emulsion side down* on the exposing surface and the document on top, in contact with the back of the paper. The image is here produced – as in the reflex process – by the difference in the light reflected from light and dark parts of the document. Bi-reflex printing requires a very thin-based document paper to reduce the inevitable diffusion of the reflected light to a minimum. Also the exposing light must be very highly diffused, and an additional diffusing sheet of white translucent plastic is usually placed between the document paper and the exposing surface of the printer.

The exposure required with the reflex and bi-reflex methods depends on the reflectivity of the white areas of the document being copied. Originals on white coated (art) paper are shortest, those on slightly yellowish paper longer. Once the correct exposure has been found for a given copying set-up and type of paper, this remains reasonably constant, subject only to the differences in the originals being handled.

Continuous-tone and half-tone originals can also be copied by reflex on a softer grade of document paper; in this case the light areas on the negative may show slight fogging due to the light passing through the document paper before being reflected from the original. The positive copies however will show clean white.

The reflex process can be carried out on an amateur scale without any need to buy special papers. Even the printing box is not essential, and a printing frame may be used. An extra hard or even hard grade of bromide paper, in conjunction with a high-contrast developer (for example No. 36 on page 443) can give very useful results. The resulting negative can then be copied by printing through it on to a similar sheet of bromide paper. The exposures are made by placing the printing frame on the baseboard of the enlarger and illuminating it by the projected light beam from the enlarger lens.

If contact papers are used, a stronger light source – for instance a 100 watt lamp about 1 metre or 3 feet from the printing frame – is necessary.



Microfilm negatives can of course be enlarged in a normal miniature or ultra-miniature enlarger. Many microfilm readers are however also suitable for making full-size enlargements. Here a mirror projects the image from the microfilm on to a screen on the front of the apparatus for reading (*top right*). On swinging the mirror aside (*bottom*) the image is projected on a sheet of enlarging paper in the base of the reader. 1, mirror of lighting system; 2, film; 3, projection lens; 4, reading screen; 5, reading mirror; 6, raised position of paper holder for small prints; 7, normal position of paper holder.

The whole layout may however be reversed with the projection unit below and the screen (and paper) in a unit on top.

Certain modern microfilm reader printers contain the paper as a continuous roll and may incorporate facilities for rapid processing by various methods to yield an enlarged print within ½ minute or less.

One purpose of copying documents in the enlarger on to a 35 mm film is to obtain microfilm negatives which provide an exceedingly space-saving way of storing information. The 35 mm cassettes available for some enlargers (page 197) hold up to 30 feet of film; this can record some 250 full-frame negatives, equivalent to (at a reduction scale of 1:18) up to 1000 pages of documents, letters or printed matter of quarto format. Yet the roll of film takes up only a fraction of the space required to store the originals.

Microfilm negatives can be kept either as complete rolls or – for easier accessibility – mounted in individual aperture cards. These are thin cards of suitable size (for instance 82 × 188 mm or $3\frac{1}{4} \times 7\frac{3}{8}$ inches) with a window incorporating either a transparent envelope or other means for holding the single microfilm negatives in place. These cards are then kept in a card index.

To refer to and read individual microfilm copies, these are placed in a microfilm reader – a modified miniature projector which projects an image at about 15 times magnification on to a translucent screen. To get positive copies, the negatives are enlarged in an ordinary enlarger (preferably at a magnification corresponding to the reduction used when copying) on to a high-contrast projection speed document paper.

A high-contrast bromide paper is also suitable. The enlargements are then processed either in the normal way or – if made on stabilization papers – in a roller processing machine.

Microfilming on a large scale is carried out with specialized copying cameras laid out in much the same way as an enlarger with lamps to illuminate the baseboard, but with film magazines taking up to a hundred feet of 35 mm film. Some microfilm cameras reduce on to 16 mm film.

Microfilm readers for commercial use may incorporate their own automatic printer. Here the image projected on a screen can be diverted (by a movable mirror arrangement) on to light-sensitive paper, generally fed from a roll. The exposed paper is processed inside the microfilm reader, yielding an enlarged print within half a minute or so. Often special photo-sensitive processes (see also page 507) are used.

Beside the classical silver halide emulsions for printing papers a number of other light sensitive systems are in use and finding various applications, including document copying. This is a rapidly expanding field of photographic technology, and we are here only very briefly outlining the main systems of importance and their principles.

Electro-photography. This depends on the discharge, by light, of electric charges on the surface of a semi-conductor. The best-known system is xerography, where a metal-backed selenium plate receives a uniform electrostatic surface charge in the dark and is then exposed to the projected image of a document, picture or other original. The exposure locally discharges the electrostatic charge in proportion to the light intensity falling on the plate. The plate is then treated with electrically charged pigment particles which adhere to the areas which have retained their electrostatic charge during the exposure. The pigment image can then be transferred on to ordinary paper and there made permanent by heating which fuses the pigment (containing a resin component for this purpose) in place.

Xerography is used exclusively for projection printing and can yield enlarged or reduced copies. It is used in automated office copiers where the image is projected on to a rotating selenium-coated drum. The various stages of charging, exposure, pigment development and transfer on to paper take place at different points around the circumference of the drum.

With suitably designed equipment this system can produce copies at a moderately high rate.

In a variant of this process the image is projected on to a specially coated and electrically charged paper. The pigment "development" and fusion of the image for permanence then take place on this paper, making the use of selenium plates or drums unnecessary.

Heat copying. Another group of copying machines employs heat-sensitive papers. These contain chemicals or dye components which under the influence of heat form coloured compounds. During the copying exposure, the document material and the original are irradiated in contact by infrared rays. The dark areas of the document being copied

absorb heat and become warm, producing a visible image in the sensitive paper layer in contact with them.

The main advantage of such thermographic systems is that they require no processing solutions whatever – the copy is finished the moment it is exposed. The images are liable to be slightly unsharp, but still readable; the copy also remains heat sensitive.

There are many variations of these thermographic processes, some involving the melting of thin wax layers or diffusion of oily substances under the influence of warming.

Thermographic copying methods are normally restricted to originals printed or drawn in pigment inks which absorb infra-red radiation. Dye images which transmit infra-red rays (and hence do not heat up) are more difficult to copy and may need special procedures.

More recent systems are based on heat-induced polymerisation reactions. One type of heat copying film for instance carries a dye layer in a water-soluble binder which hardens and becomes insoluble on heating. To produce an image, the film is placed with its emulsion side in contact with the surface of the original and the two run through a thermocopying unit. The exposure takes place through the film base and through the dye layer; the heat reflected from the black portions of the original selectively hardens the image forming layer. All non-exposed parts are washed out on subsequent treatment with water, leaving a dye image which is positive with respect to the original.

As different dyes can be used in this process, such heat copying films can yield a variety of monochrome colour images – e.g. white, yellow, red, green, blue, black etc. By using several differently coloured films and copying from separation originals, it is even possible to produce multicoloured combinations by superimposition.

Dry copying. Superficially related to heat copying are dry copying processes based on materials containing processing chemicals which are activated by heat and using systems such as micro-encapsulation (page 453). One such system involves the use of an intermediate tissue coated with light-sensitive silver compounds. This tissue is exposed in contact with the original to be copied – for instance by a reflex set-up (page 502). The exposure here decomposes or otherwise affects the light sensitive sub-

stances without however forming at this stage a visible image. The tissue then passes between heated rollers in contact with a specially prepared positive paper containing micro-encapsulated dye coupling substances. These react with the unexposed compounds in the tissue, forming a visible dye image. The tissue in effect has the role of an intermediate negative, so that the final image is positive.

By using selectively colour sensitive compounds, each with coupling elements complementary to their sensitivity, it is again possible to obtain colour reproductions in the final copy. Thus red-sensitive elements might contain coupler substances capable of forming cyan, green-sensitive elements to yield magenta and so on. The dyes of the colours themselves are formed in the single layer of the final positive. The colour quality of such colour copying processes is not comparable with the reproduction of high-quality colour photography – nor is it intended to be: in the reproduction of for instance engineering drawings with colour coded items indicative rather than faithful reproduction is required. (In other words what matters is that blue should reproduce as blue, green as green etc., without strict requirements as to the exact shade of the blue or green.)

Dyeline copying. Here light sensitive dye components are decomposed or otherwise changed by exposure to ultraviolet radiation. On subsequent treatment of the exposed paper with ammonia vapour or certain solutions (their composition depends on the actual compounds used in the sensitive paper) either the exposed or the unexposed areas (according to the process) form a visible dye image.

Dyeline printing materials are very cheap, and this method is therefore widely used for duplication on a fairly large scale. It is however confined to printing through the original. So the latter must be transparent or at least translucent, and suitable dyeline masters can be prepared from document originals by normal reflex copying on to a thin or transparent-based document material. Also, dyeline printers need an ultra-violet source. Automatic printers of this type can turn out hundreds of copies per hour. The process is generally confined to contact printing, but special enlargers exist, using a high-power mercury lamp to permit even enlarged copies from, for instance, microfilm negatives.

Dry dye printing. Some of the latest printing processes involve neither liquid chemical reactions nor heat; their image forming processes are entirely controlled by light of selected wavelengths. Here one type of light may have an activating function and light of another wavelength a stabilising effect. Typically, such a material consists of a sensitive layer containing photo-initiators and colourless leuco dye molecules. On exposure to ultra-violet radiation, the photo initiators react with the leuco-compounds to form coloured dyes. Exposure to visible light deactivates the photo initiators, so making further dye formation impossible.

Dye printing systems of this kind can yield images in numerous colours. This permits the production of multicolour prints by superimposition of several dye images; such materials are used for instance in making large-size transparencies for overhead projection.

Such dye systems can function in a negative or a positive mode and may be suitable for continuous-tone as well as line pictures. For instance to obtain a positive from a negative, the dye printing material is exposed through the negative to ultra-violet radiation. The unexposed image areas are then deactivated ("fixed") by exposure to visible light. To obtain a negative from a negative, the material is exposed through the original negative to visible light. This deactivates the shadows of the image; subsequent exposure – without the negative – to ultra-violet rays then converts the previously unexposed areas to dye.

A further advantage is the immediate accessibility of the images after exposure. Moreover, if the material is not deactivated after the first exposure to ultra-violet radiation, further images can be added by subsequent exposures through different negatives or positives.

In addition to the above, the fast growing range of other light-, ultra-violet- and heat-sensitive systems is finding increasing use for various copying purposes. Most of these require special equipment, not only to deal with the specific system requirements, but also to provide the necessary automation in use. This is essential to make such systems economical on a large scale.

Faults in Enlargements

This catalogue of failures is comprehensive not in order to frighten the photographer, but to give the widest scope in tracking down faults which may occur in the enlarging process. Even so it has to be confined to the reasonably common mistakes, partly at least because some of the rarer faults are often associated with one specific make of material, processing solution or type of exposing or processing equipment.

Further, the following lists assume that the starting point of the enlarging process, namely the negative, is of good quality. Obviously blurred, badly over or under-exposed- and damaged negatives cannot but reproduce their individual flaws in every print made from them.

DENSITY AND CONTRAST IN MONOCHROME PRINTS

(1) *Flat print showing insufficient density in the shadow tones, but adequate highlight detail.*

- (a) The paper was too soft for the negative (page 241).
- (b) The print was over-exposed and underdeveloped (page 241).
- (c) The developer was too dilute, too cold or exhausted (page 324).

(2) *Hard print, with insufficient detail in highlights and dense shadows.*

- (a) The paper was too contrasty for the negative (page 241).
- (b) If contrast is only slightly too great, the print was under-exposed and overdeveloped (page 325).

(3) *Print too light, but appears reasonably correct in contrast.*

- (a) The print was under-exposed (page 241).
- (b) The developer was too cold, exhausted or development too short (page 324).

(4) *Print too dark, with highlights veiled.*

- (a) The print was over-exposed (page 241).

(b) Development was too long (if the print is only slightly too dark).

TONES AND STAINS IN BLACK-AND-WHITE PRINTS

(5) *General fog over whole print.*
   (a) The paper was stale or badly stored.
   (b) The darkroom safelight was too bright or too near the paper during handling or processing (page 210).
   (c) Stray light may have penetrated around the edges of an insufficiently masked negative in the negative carrier (page 252).
   (d) The paper may have been fogged by accidental exposure before printing.
   (e) The developer contained too little potassium bromide, was too concentrated or too warm (page 330).
   (f) Stray light from the enlarger or insufficiently blacked-out darkroom.

(6) *Black edge fog on the print.*
   (a) The paper has been stored in a damp or too warm room.
   (b) Chemicals or fumes have affected the emulsion of the print before exposure and development.
   (c) White light was accidentally turned on in the darkroom while a box or packet of papers was insufficiently wrapped up. In this case the top sheets are likely to be fogged all over, but other sheets may show fog only along one or two edges.

(7) *Greenish-black image tone.*
   (a) The print was not fully developed (page 324).
   (b) The developer was stale or exhausted.
   (c) The developer contained too much potassium bromide (page 330).
   (d) The paper was stale or badly stored.

(8) *Mottled or patchy image tones in print.*
   (a) The print was greatly over-exposed and under-developed (page 325).
   (b) Stale paper, stale developer or exhausted developer, as in (7) above. Poor image tones due to stale paper can usually be avoided by adding developer improver to the developer solution (page 331).

(9) *Comparatively sharp areas of uneven density.*

The developer only covered part of the paper surface during the first few seconds of development. This may be due either to unskilled handling or to too small a quantity of developer in the dish.

(10) *Print turns yellow or brown on keeping.*

(a) If the highlights turn yellow, the print was insufficiently fixed (page 345).

(b) If highlight as well as image details turn brown or yellow, the print was insufficiently fixed or insufficiently washed (page 350).

(c) The print was mounted with a paste containing free acid or sulphur compounds (unsuitable rubber mountants), or the mount contained impurities (such as free chlorine or other oxidising agent).

(d) In the case of stabilization processed prints (page 348): exhausted stabilizer, or the print was washed after stabilization.

(11) *Print turns brown or yellow-brown either in the developer or in the fixing bath.*

(a) Excessively long development or too warm developer.

(b) The developer contained too little potassium bromide or was contaminated with hypo (page 324).

(c) Insufficient rinse between development and fixing (page 342).

(d) The fixing bath was contaminated with developer, or not sufficiently acid (page 342). An acid stop bath is a useful safeguard against this.

(12) *Yellow or brown stains over whole print.*

(a) The prints have stuck to each other during fixing and have only been partially fixed (page 345).

(b) The prints were exposed to white light while still largely unfixed.

(c) The prints were not kept below the surface of the fixing bath, so that part of the emulsion was not in contact with the solution.

(d) Prints were insufficiently rinsed between development and fixing.

(e) The fixing bath was exhausted or insufficiently acid (page 346).

(13) *Print unsharp overall (assuming that the negative was sharp).*

(a) The enlarger was incorrectly focused. In an automatic focusing enlarger this may be due to wear on the cam surfaces or lack of correction of the focusing system for the thickness of the masking frame or paper holder.

(b) The optical correction of the enlarging lens was inadequate, resulting in change of focus on stopping down.

(c) The negative was not properly flat in the enlarger carrier.

(d) The enlarger lens was very dusty or the lens components have become uncemented. In either case the lens looks dark or patchy and not correctly transparent.

(e) The enlarger vibrated during the exposure (page 245).

(f) In contact printing the printing frame or box did not hold the negative and the printing paper in optical contact.

(14) *Print partly unsharp and partly sharp.*

(a) The enlarger lens was of inadequate optical correction with an insufficiently flat field.

(b) The negative was not sufficiently flat in its carrier in the enlarger.

(c) The planes of the negative, enlarging lens and paper were not strictly parallel. Where either of these is tilted to correct converging verticals, the lens must be stopped down sufficiently to ensure overall image sharpness (page 401).

(15) *Image reversed left to right.*

The negative was placed the wrong way up in the enlarger or contact printer.

(16) *Print lighter or darker in the centre of the image than at the edges (assuming even density distribution in the negative).*

(a) The enlarger lamp was not correctly adjusted for even illumination (page 121).

(b) The enlarger lens had too short a focus to cover the negative format adequately (page 141).

(17) *Print lighter at one edge than at the other.*

(a) The negative in carrier of the enlarger was not parallel with the paper on the baseboard. Where the negative or paper is inclined to correct converging verticals, the print may need progressive shading from one side to the other (page 402).

(b) The negative or negative carrier was not correctly centred in the optical axis, so that one side was too near the limit of coverage of the enlarger lens.

SPOTS AND OTHER FLAWS

(18) *Scum and roughness on the print surface.*

Caused by hard water: the particles are chalk scum. The scum may be removed by bathing the print briefly in 2 per cent acetic or hydrochloric acid.

(19) *Black and more or less sharp spots (when not due to faults on the negative itself).*

(a) Particles of developing chemicals have remained undissolved in the developer (for example by incorrect making up or dissolving developer powder in cold water).

(b) The stop bath did not fully flood the print after development, and development continued at points where air bubbles formed (page 342).

(c) Air bubbles have formed on the print emulsion in the fixing bath, locally inhibiting fixation. These points turn black later on exposure to light.

(20) *Pencil-like black marks on the print.*

The emulsion surface has been rubbed before development, resulting in stress marks.

(21) *Small white spots with sharp edges, sometimes with a thin black ring round them.*

(a) Air bubbles remained on the emulsion during development.

(b) Small impurities were present in the paper.

(22) *Tiny white irregular spots, sometimes in the form of short hairlines.*

Dust settled on the negative during exposure. These spots, like those caused by air bells (21) must be removed by spotting (page 456).

(23) *Irregular ring-shaped markings, alternately light and dark on the print (Newton's rings).*

Caused by incomplete contact between the negative and the glasses in the negative carrier of the enlarger. May disappear if the pressure on the negative is reduced; cannot arise in a glassless carrier.

(24) *Air bells or blisters between emulsion and paper base.*

(a) Excessive differences in temperature were present between the developer and stop bath or stop bath and fixer.

(b) Too concentrated or strongly alkaline developer was followed by too acid stop bath or fixer.

(c) Occasionally this fault is caused by too concentrated fixing bath.

GLAZING FAULTS (NOT PLASTIC-COATED PAPERS)

(25) *Brown marks on hot glazed prints.*

(a) Prints were insufficiently fixed.

(b) Prints were insufficiently washed. The silver salts remaining in emulsion in either case change to silver sulphide under the influence of heat from the glazer.

(26) *Matt or unglazed spots or areas.*

(a) Air bubbles were present between the print and the glazing plate (page 362).

(b) The glazing plate was not properly cleaned before use (page 362).

(c) Prints were squeegeed down too hard or not hard enough.

(27) *Prints refuse to glaze.*

The prints were left for too long in an acid hardening fixer.

(28) *Oyster shell or wavy markings on glazed prints.*

(a) Prints were peeled from the glazing plate before they were properly dry.

(b) Prints were allowed to dry too rapidly without adequate pressure to keep them in contact with the glazing plate.

(29) *Fine scratches and other marks on glazed print surface.*

(a) The glazing plate was scratched or otherwise damaged.

(b) Small particles of grit remained between the print and the glazing surface.

(30) *Glazed prints stick to the glazing plate.*

(a) The glazing plate was dirty.

(b) Scum settled on prints due to extremely hard water.

(c) Mechanical damage of glazing plate or attack by acid vapours. (This may occur with chromium glazing plates stored in a damp atmosphere.)

MOUNTING FAULTS

(31) *Paste-mounted prints refuse to stick.*

(a) Too much – or too little – mountant was used.

(b) The print was applied to the mount while too wet.

(c) Paste unsuitable for plastic coated paper.

(32) *Rubber mounted print won't stick.*

(a) Mountant was not applied to both print and mount.

(b) The print was applied to the mount while the mountant was still too wet.

(33) *Print and mount cockled.*

(a) The mounted print was not allowed to dry under pressure.

(b) No backing sheet to counteract the pull of the mounted print was applied to the mount (page 462).

(34) *Rubber mounted print peels off mount.*

(a) Insufficient mountant was used, especially if the surface of the mount was rough.

(b) Deterioration of mountant. This is inevitable after a time.

(35) *Surface marks on mounted print.*

(a) Particles of grit or other foreign matter were enclosed between the print and the mount.

(b) Insufficiently close contact between the print and the mount over their whole area, permitting air bubbles to form during mounting.

(c) The print was not smoothed down thoroughly during mounting.

(36) *Dry-mounted print does not adhere to mount.*

(a) If the tissue adheres to the print but not to the mount, the temperature of the mounting press was too low.

(b) If the dry-mounting tissue adheres to the mount but not to the print, the temperature of the mounting press was too high.

(c) If the print adheres unevenly, heat or pressure was not applied uniformly over the whole print surface. (This liable to occur where a flat iron is used for dry mounting – a properly designed dry mounting press gives even heat and pressure.)

(37) *Dry-mounting tissue protruding from edge of mounted print.*

(a) The print was not absolutely dry before mounting, and contracted during the application of heat.

(b) The print with attached dry-mounting tissue was not trimmed evenly. The use of dry mounting solution on the back of the print (page 464) avoids this trouble.

COLOUR PRINTS FROM COLOUR NEGATIVES

(38) *Image too dark but colour balance satisfactory.*

(a) The print was over-exposed. With tri-colour printing the exposures through all three filters must be reduced in the same ratio.

(b) The print was developed too long or in too warm developer.

(39) *Image too light but colour balance satisfactory.*

(a) The print was underexposed. In tri-colour printing all three exposures must be increased by the same ratio.

(b) The print was underdeveloped or the developer was too cold.

(c) The colour developer was exhausted.

(40) *Predominant overall tint of one colour but clear margins.*

(a) White light (subtractive) printing: the filter combination in the filter pack was wrong. If the print density is satisfactory, the exposure must also be adjusted when changing the filter pack to allow for different filter factors.

(b) Three-exposure (additive) printing: the ratio of the exposures through the three filters was incorrect. After adjusting the ratio, increase or decrease all three exposures in the same proportion to obtain the same total exposure again (page 288).

(41) *Uneven colour cast, predominantly one colour in highlights and a different colour in shadows.*

(a) Gross lack of balance in the colour negative due to over- or underexposure, or use of mixed lighting for the subject.

(b) The colour paper was not suitable for the type of colour negative being printed. This may arise when printing masked (orange-tinted) colour negatives on paper intended for non-masked negatives, or vice versa (see page 112). Proper colour balance then may call for heavy filtering or disproportionate exposures through the three filters in tri-colour printing. This can lead to reciprocity failure so that the characteristics of the three sensitive layers of the colour paper no longer match the way they should.

(42) *Dirty yellows or cyan cast which cannot be removed by filtering correction, or by exposure correction in tri-colour printing.*

The colour paper is infra-red sensitive, and no heat absorbing filter was used between the lamp and the negative in the enlarger.

(43) *Colour balance of final print does not match colour balance (or depth) of test print on which it was based.*

(a) The test and final prints were not made under identical conditions.

(b) Voltage variation in the mains supply caused a change in the colour temperature of the enlarging light. Constant voltage equipment or at least a frequent check on the mains voltage is desirable in colour enlarging.

(c) The processing solutions were appreciably more exhausted when the final print was made than for the test.

(d) Different batches of colour paper were used for the test and for the final print.

(44) *Colour cast on print exposed after colour grading by integration to grey.*

This is usually due to a subject of abnormal colour distribution which is unsuitable for this type of colour analysis (page 297).

(45) *Dull and lifeless colour print.*
(a) The negative was too soft for the colour paper being used.
(b) The print was underdeveloped or processed in exhausted developer.

(46) *Harsh and contrary print, with detailless highlights and heavy shadows.*
(a) The negative was too contrasty for the colour paper, or underexposed.
(b) The print was overdeveloped or developed in too warm a developer.

(47) *Stained highlights but clean borders on print.*
(a) The print was overexposed.
(b) Stray light reached the paper during the exposure.

(48) *Stained highlights and borders on print.*
(a) Exhausted or stale developer was used.
(b) The processing temperature was too high.
(c) The colour developer was incorrectly compounded or a formula was used which was not suitable for the colour paper employed.
(d) The print was not rinsed sufficiently between development and the subsequent steps. Always follow exactly the processing procedure recommended by the manufacturer of the paper.
(e) The paper was fogged by unsafe darkroom lighting or white light before or during processing.

(49) *Colour fringes in colour enlargements.*
(a) If the fringes appear only in the edge portions of the print but not the centre, the enlarger lens was not sufficiently corrected for colour work.
(b) If the fringes – and blurring – are uniform over the whole print, the enlarger or the paper was moved during the exposure. This may be either enlarger vibration or slight movement of the enlarger when changing filters during tri-colour printing.

(50) *Discoloration of parts of the print.*
(a) The bleaching, fixing or bleach-fixing bath was exhausted.
(b) The print was dried by excessive heat. Colour

papers vary in the amount of heat that they will stand during drying.

COLOUR PRINTS FROM TRANSPARENCIES

(51) *Image too light.*
- (a) If the highlights are black, the print was over-exposed.
- (b) If the image contrast is also very high, the first development was excessive.
- (c) If the contrast is too low, colour development was too short.

(52) *Image too dark.*
- (a) If the shadows are blocked up, the print was under-exposed.
- (b) If the print contrast is too low, first development was insufficient.
- (c) If the print contrast is high, colour development was too long.

(53) *Predominant overall tint or colour cast.*

This is due to the same causes as with colour prints made from colour negatives – see (40) above. The necessary filtering or exposure balance corrections are however the opposite to those required for printing from colour negatives (see page 322).

(54) *Poor colour reproduction which cannot be corrected by filtering.*

This is usually a sign of a transparency unsuitable for printing, either because of excessive brightness range or due to inherent colour faults in the transparency itself.

(55) *Other colour faults, such as stains, fringes and discoloration arise for much the same reasons as when printing from colour negatives – see Nos.* (47) *to* (50) *above.*

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